Replacement of fish meal by *Lucilia sericata* (Meigen, 1826) live larvae and powdered meal in production of stinging catfish *Heteropneustes fossilis* (Bloch, 1794) post-larvae

[1]Abdus Satter, [2]Md. Ahsan Bin Habib, [3]Abdulla-Al-Asif, [3]Hadi Hamli, [4]Amir Hossain

[1]Department of Fisheries, Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University, Melandah, Jamalpur-2012, Bangladesh; [2]Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh; [3]Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia; [4]International Studies in Aquatic Tropical Ecology (ISATEC), Department of Biology, University of Bremen, Bibliothekstraße 1, 28359 Bremen, Germany. Corresponding author: H. Hamli, hadihamli@upm.edu.my

Abstract. Reduction of aquaculture operations and production cost is key to the success and profitability of this enterprise, while protein needs, especially the cost of fish meal, are cery expensive. The current study was conducted to investigate the post-larval production performance of *Heteropneustes fossilis* using *Lucilia sericata* maggot as a fish meal replacer in two ways, namely, live larvae and powder form. A 28 days growth trial was performed where five isonitrogenous diets for *Heteropneustes fossilis* post-larvae were experimented using live maggots and maggot meal, respectively. The proximate composition of each formulated diet, growth parameters of fish post-larvae, such as, weight gain, specific growth rate, protein efficiency ratio, apparent protein utilization, survival rate and the food conversion ratio were examined. After the experiment, the carcass composition of the experimental fishes were evaluated. The best final weight (1.61 g), weight gain (1.418 g), percentage of weight gain (739±1.18%), specific growth rate (2.63), protein efficiency ratio (2.29), apparent protein utilization (85%), survival rate (90%) and lower food conversion ratio (2.06) were observed in fish fed with 75% maggot meal as a substitute of fish meal. This study will help the aquaculture industry, especially the catfish culture in identifying an alternate source of protein and lowering the cost of aquaculture operation.

Key Words: aquaculture, alternative protein source, common green bottle fly larvae, poultry waste.

Introduction. There are different types of agro-industries such as sugar mills, fertilizer factories, poultry farms in Bangladesh which discharge a huge amount of waste matter and effluent in waterways and other terrestrial places, while management of these wastes remains a challenge for government and other stakeholders (Alam & Hossain 2009; Ayilara et al 2020; Modak et al 2019; Reza & Islam 2019; Samad et al 2011). The wastes discharged from poultry farms may be used to recycle nutrients through production of fly larvae, microalgae, bacteria and fungus (Boaru et al 2018; Glatz et al 2011; Gold et al 2020; Markou et al 2018). These wastes contain high organic nutrients, biological oxygen demand (BOD) and chemical oxygen demand (COD), total dissolved solids, total suspended solids, nitrate-N, Ammonia-N, Phosphate-P and inorganic nutrients (Abdel-Raouf et al 2012; Habib et al 2005; Izzah et al 2020; Kwon et al 2020; Yaseen & Scholz 2019). These organic and inorganic nutrients in wastes help to grow microalgae as well as the biosynthesis of high amounts of protein, lipids, carbohydrates and ash (Melo et al 2018; Su et al 2022). Among the wastes, poultry waste (PW) may be used for high biosynthesis of protein, lipids and carbohydrates in fly larvae, microalgae, bacteria and fungus

(Cammack & Tomberlin 2017; Hasnol et al 2020). These nutrients can be utilized by fly larvae especially common green bottle fly (*Lucilia sericata*) larvae as an inexpensive medium (Firoozfar et al 2011; Mazza et al 2020; Parry et al 2020; Zhang et al 2021).

In addition to its attractive deliciousness, stinging catfish (*Heteropneustes fossilis*) is very nutritious because of its high protein content (Anwar & Jafri 1995; Bezbaruah & Deka 2021; Salma et al 2021). The market value of this species was found higher than most fishes available in the local markets of Bangladesh, and thus aquaculturists labeled culturing of this catfish as highly profitable (Hasan et al 2022; Samad & Bhuiyan 2017). *H. fossilis* is mainly carnivorous, its main diet comprise crustaceans, animal matter and worms, and the rearing of this fish requires high protein content feed (Bhattacharjee & Chandra 2016; Fatma & Ahmed 2020; Narejo et al 2016). The aquaculture of this species is not new in south Asian countries, but the major cost of production of this species lies in the high protein value feed, as the price of protein has remained consistently high in the market (Das et al 2021; Samad et al 2017; Zafar 2020). The breeding biology, induced breeding in captive environment and the sex reversal of this species were well studied (Ali et al 2016a; Ali et al 2016b; Haniffa et al 2004; Hasan et al 2022; Rahman et al 2013). It is well established that this carnivorous fish can grow fast if fed with fly larvae, live foods available in aquatic body as well as good quality diet (Narejo et al 2016). Catfishes can also feed well and exhibit excellent growth when fed on common green bottle fly larvae, *Chironomus* fly larvae and annelids (Bhattacharjee et al 2009; Nogales-Mérida et al 2019; Tran et al 2015).

Reducing the operating cost was identified among the major challenges in aquaculture enterprise and business, while most of the cost incurred is for the feed, notably protein (Dickson et al 2016; Fry et al 2018; Hua et al 2019; Hyuha et al 2011). In addition to the fact that fish meal is a vital element in the composition of fish feed, the importation of fish meal from another nation (and occasionally another continent) has caused the price of raw fish meal to rise significantly (Cashion et al 2017; Choi et al 2020; Tacon & Metian 2008). In today's world, experts are interested in replacing the present protein sources used in aquaculture with insects, larvae, live feed, plant protein sources, among other sources (Papuc et al 2020; Al-Thobaiti et al 2018; Chen et al 2019; Egerton et al 2020; Tippayadara et al 2021). The future of the protein business may be derived from insects, particularly arthropod species; research is now underway to identify alternative sources of protein and people in several African nations use insects as their primary source of protein (Alfiko et al 2021; Gałęcki et al 2021; Lange & Nakamura 2021; Nugroho & Nur 2018). This experiment was carried out to examine the production of *Lucilia sericata* maggot and its usage as a fish meal substitute for the production of post-larvae, as well as the growth of stinging catfish (*H. fossilis*) when fed with live and powdered maggot, respectively.

Material and Method

Study area and periods. The experiments were conducted from the Wet laboratory, Department of Aquaculture and laboratory of the Department of Animal Nutrition, Bangladesh Agricultural University (BAU), Mymensingh from January 2016 to May 2016. All the analyses such as proximate composition of fly larvae, prepared feed and carcass composition of fish post-larvae were performed from the Fish Nutrition laboratory, Department of Aquaculture and Central laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Collection of common green bottle fly (L. sericata) larvae. The common green bottle fly (*L. sericata*) usually lays eggs on raw PW and their larvae grow in this medium. The flies were identified following the keys given by Holloway (1991) and Williams and Villet (2014). The flies were collected from a nearby poultry farm situated at Sutiakhali, three km away from Bangladesh Agricultural University, Mymensingh.

Experimental design. Five experimental diets including control were prepared to feed stinging catfish (*H. fossilis*) post-larvae. Fifteen rectangular glass aquaria (45 cm×40 cm×35 cm) of 50L capacity containing about 40 L of water were used as experimental tanks. In each aquarium, water level was maintained by supplying recirculated water. Water level was controlled by an overflow standpipe placed directly in the drain line at the middle of the aquarium. Net screens gravels were used as bio-filter to serve dual function: solid capture and bio-filtration, as well as removing toxic waste products that were produced by the fish.

Collection of stinging catfish post-larvae. Post-larvae of stinging catfish (*H. fossilis*) of the same age group (10 days old) were collected from a farm in Shombhuganj, Mymensingh, Bangladesh. They were carried to the laboratory through proper handling.

Acclimatization of post-larvae. Upon reception at the laboratory, the fingerlings were fed an iodine salt treatment with 0.5% NaCl solution for seven days in three aquaria with sufficient aeration.

Experimental procedure. The experiment was carried out in 15 glass aquaria with five different treatments, each of which had three replications. The acclimatized fishes were reared for 28 days. The post-larvae of stinging catfish (*H. fossilis*) (mean initial weight 0.192 ± 0.02g; mean initial length, 5-6mm) was used as experimental animal. The post-larvae were dispersed at a rate of 40 fish per aquaria in a random manner. During the removal of uneaten feed and feces from each tank, the water in each aquaria was half changed every day.

Live feed formulation. Use of maggot as live feed for *H. fossilis* post-larvae production was designed where in 20 maggots were fed in treatment 1, 40 maggots were fed in treatment 2, 60 maggots were fed in treatment 3, 80 maggots were fed in treatment 4, and fish meal was used in treatment 5 which was also considered as the control treatment (Table 1).

Table 1

Feed containing four different levels of live maggot, and a control diet

Ingredients (%)/Treatments	*T1*	*T2*	*T3*	*T4*	*T5*
Fish meal	-	-	-	-	53.57
Live maggot	20	40	60	80	-
Dry matter (on 16% basis)	3.20	6.40	9.80	12.80	-
Wheat flour	-	-	-	-	25
Soybean oil	-	-	-	-	5
Vitamin premix	-	-	-	-	2
Mineral premix	-	-	-	-	3
Chromic oxide	-	-	-	-	1
α-Cellulose	-	-	-	-	10.43
Total	-	-	-	-	100
Crude protein (%)	11.20	22.40	33.60	44.80	30

Maggot meal feed formulation. Five isonitrogenous diets were formulated containing 30% protein, 8-10% lipid, 4-6% crude fiber and variable 40% of digestible carbohydrate source (Habib et al 2001; NRC 1983). When formulating the diet, the necessary fatty acid content was considered by altering the soybean oil used in cooking. Chromic oxide (0.50%) was added to each prepared diet for the subsequent study of protein utilization and digestibility (Austreng 1978; Fernandez et al 1999; Furukawa & Hiroko 1966) (Table 2).

Table 2

Formulation of diets of 30% crude protein containing four different levels of maggot meal for stinging catfish (*H. fossilis*), and a control diet

Ingredients (%)/Treatments	*T1*	*T2*	*T3*	*T4*	*T5*
Fish meal	40.18	26.79	13.39	-	53.57
Maggot meal	13.25	26.50	44.17	53	-
Wheat flour	25	25	25	25	25
Soybean oil	5	5	5	5	5
Vitamin premix	2	2	2	2	2
Mineral premix	3	3	3	3	3
Chromic oxide	0.50	0.50	0.50	0.50	0.50
α-Cellulose	11.57	11.21	6.94	11.50	10.93
Total	100	100	100	100	100
Protein from fish meal	22.50	15	7.50	-	30
Protein from maggot powder	7.50	15	22.50	30	-

Note: Diet 1 (75% Fish meal + 25% Maggot meal), Diet 2 (50% fish meal + 50% maggot meal), Diet 3 (25% fish meal + 75% maggot meal), Diet 4 (100% maggot meal) and Diet 5, control diet (100% fish meal).

***Feeding strategy**.* The experimental fish were given the formulated meals three times daily during the research period: at 9.00 a.m., at 1.00 p.m., and at 5.00 p.m. The remaining feed was dumped into the tank and then removed by syphoning. Post-larvae in every aquarium were fed at a rate of 6% of their total body weight. The quantity of food consumed was recorded to calculate the food conversion ratio and protein efficiency ratio.

***Sampling procedure**.* To evaluate growth performance of the experimental fish, random individual checking was used to sample the fish at intervals of 7 days. Growth of fish post-larvae in each sampling was taken by weighing the sampled fish using a weighing electrical balance (BS 224S; ±0.1mg).

***Collection and preparation of fish post-larvae for sample carcass composition**.* A total of 200 fishes were gathered and ten fishes from each replication were randomly selected, sacrificed then chopped, dried in oven at 50°C for two days, grinded, sieved and packed in polythene bag, kept in freezer and used for proximate composition analysis in triplicates.

Analytical methods for fly larvae (maggot), feed ingredients, feeds, and carcass composition of fish. Proximate composition such as moisture, crude protein, crude lipids, ash and nitrogen free extract (NFE) of feed ingredients, experimental feed and fish carcass compositions were analyzed according to standard procedures given by Association of Official Analytical Chemists (AOAC 2005) and Hamli et al (2021). Growth parameters such as weight gain (%), FCR (Food conversion ratio), SGR (Specific growth rate), PER (Protein efficiency ratio) and survival rate (%) were analyzed following Enyidi et al (2017), Faruk et al (2018), Billah et al (2019), and Islam et al (2021).

Analysis of growth parameters of fish post-larvae. The growth parameters such as, mean weight gain, percent weight gain, SGR %/day, FCR, PER, apparent protein utilization (APU) and NFE were calculated following formulas:

$$\text{Mean weight gain} = \text{Mean final weight} - \text{Mean initial weight}$$

$$\text{Percent weight gain} = \frac{\text{Mean final weight} - \text{Mean initial weight}}{\text{Mean initial weight}} \times 100$$

$$\text{SGR (\%/day)} = \frac{\text{LnW2} - \text{LnW1}}{\text{T2} - \text{T1}} \times 100$$

where: W_1 = the initial live body weight (g) at time T_1 day; and W_2 = the initial live body weight (g) time T_2 day.

$$FCR = \frac{\text{Feed fed (dry weight t)}}{\text{Live weight gain}}$$

$$PER = \frac{\text{Live weight gain (g)}}{\text{Crude protein fed (g)}}$$

$$\text{Apparent Protein Utilization} = \frac{Nb - Na}{Ni} \times 100$$

where: Na = body nitrogen at the start of the experiment; Nb = body nitrogen at the end of the experiment; and Ni = Amount of nitrogen ingested.

NFE=100 – (moisture + crude protein + crude lipids + ash + crude fiber)

Statistical analysis*.* One-way analysis of variance (ANOVA) was used to compare the variation of proximate compositions and growth parameters of fish post-larvae, fed different diets using SPSS 25 (IBM SPSS Statistics) (SPSS 25 2016). The means were compared and identified the presence of significance using Tukey test.

Results

Proximate composition of feed ingredients and fly larvae. The fly larvae (maggot) contained high crude protein (56.60±0.25%), crude lipids (15.80±0.10%) and ash content (15.40±0.07%) with a Nitrogen Free Extract (NEF) value of 1.22±0.02; while the fish meal comprised 56.0±0.23% of crude protein, 11.21±0.07% of crude lipid, 13.34±0.08% of ash content with a 3.25±0.03 value of NEF. On the other hand, the wheat flour comprised lower protein (10.20±0.105), crude lipid (2.10±0.04%), ash content (2.40±0.04%), crude fiber (1.78±0.03%) and high NFE (73.06±0.45) (Table 3).

Table 3

Proximate composition (%) of fish meal, maggot and wheat flour (dry weight basis)

Name of the ingredients	*Moisture (%)*	*Crude protein (%)*	*Crude lipids (%)*	*Ash (%)*	*Crude fiber (%)*	*NFE*
Fish meal	10.70±0.10	56.0±0.23	11.21±0.07	13.34±0.08	4.70±0.03	3.25±0.03
Maggot	10.88±0.10	56.60±0.25	15.80±0.10	15.40±0.07	-	1.22±0.02
Wheat flour	10.45±0.10	10.20±0.10	2.10± 0.04	2.40±0.04	1.78±0.03	73.06±0.45

Post-larval production of stinging catfish (Heteropneustes fossilis) using live fly larvae*.* The stinging catfish post-larvae (initial weight 0.192±0.01 to 0.193±0.01g) were fed four treatments of live maggot and a control diet with fish meal formulation (Table 2). After 28 days of rearing, it was observed that T3 had the significantly highest ($p<0.05$) final weight (1.55g), followed by T5 (1.495g), T2 (1.35g), T4 (1.25g) and T1 (1.16g). On the other hand, T3 (1.356g) and T5 (1.303g) showed the significantly highest weight gain during the experimental period, followed by T2 (1.157g), T4 (1.058g) and T1 (0.967g) (Figure 1).

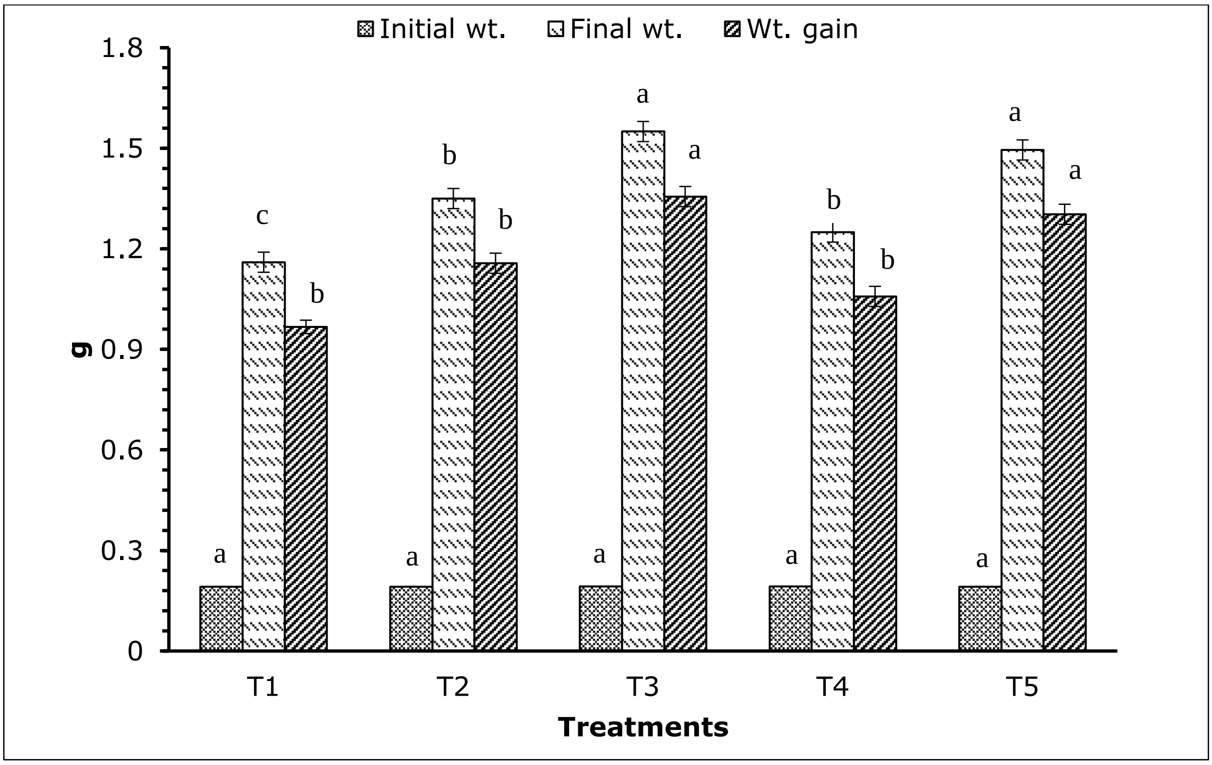

Figure 1. The growth parameters of stinging catfish fed four different diets of fresh maggot, and a control diet. Different alphabet letters between columns indicated significant differences at p<0.05.

The weight gain percent (%) of stinging catfish fed with live maggot T3 (699±1.50%) formulation was significantly the highest (p<0.05) among the treatments, followed by T5 (679±1.45%), T2 (600±1.13%), T4 (551±1.12%) and T1 (501±1.12%) (Table 4).

Table 4

Growth performances of stinging catfish (*H. fossilis*) post-larvae fed with four treatments of live maggot diet, and a control diet

Growth parameters	*T1*	*T2*	*T3*	*T4*	*T5*
Weight gain (%)	501±1.12^{c}	600±1.13^{b}	699±1.50^{a}	551±1.12^{c}	679±1.45^{a}

Note: Different alphabet between columns indicated significant at p<0.05.

The weekly growth trends were highest in catfish post-larvae fed with T3 live maggot formulation; weight gain reached 0.581g in the first week, 0.997g in the second week, 1.334g and 1.55g in the third and fourth weeks respectively. On the other hand, T1 showed the lowest growth trends amongst all the treatments: 0.437g, 0.712g, 0.972g and 1.16g in the first, second, third and fourth weeks respectively. Therefore, T1 showed the least growth (Figure 2).

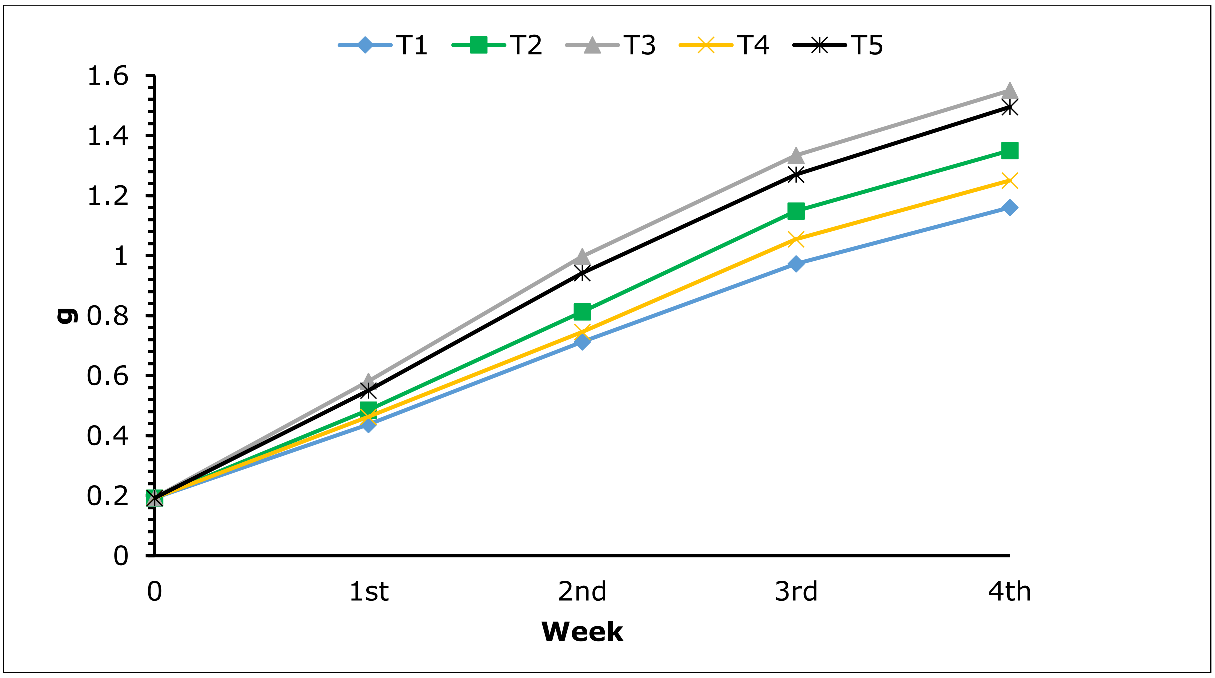

Figure 2. Weekly weight gain (g) trends of stinging catfish fed live maggot diets and fish meal formulation.

The specific growth rate (SGR) of catfish post-larvae fed with live maggot T3 (2.73) and T5 (2.61) formulations were found to be significantly ($p<0.05$) higher amongst the treatments, followed by T2 (2.46), T4 (2.42) and T1 (2.35) whereas the food conversion ratio (FCR) of T3 (2.08) found to be the significantly lowest followed by T5 (2.14), T4 (2.35), T2 (2.40), and T1 (2.49). On the other hand, the protein efficiency ratio (PER) of T3 (1.75) and T5 (1.68) were found significantly higher amongst the treatments followed by T2 (1.51), T4 (1.48) and T1 (1.42) (Figure 3).

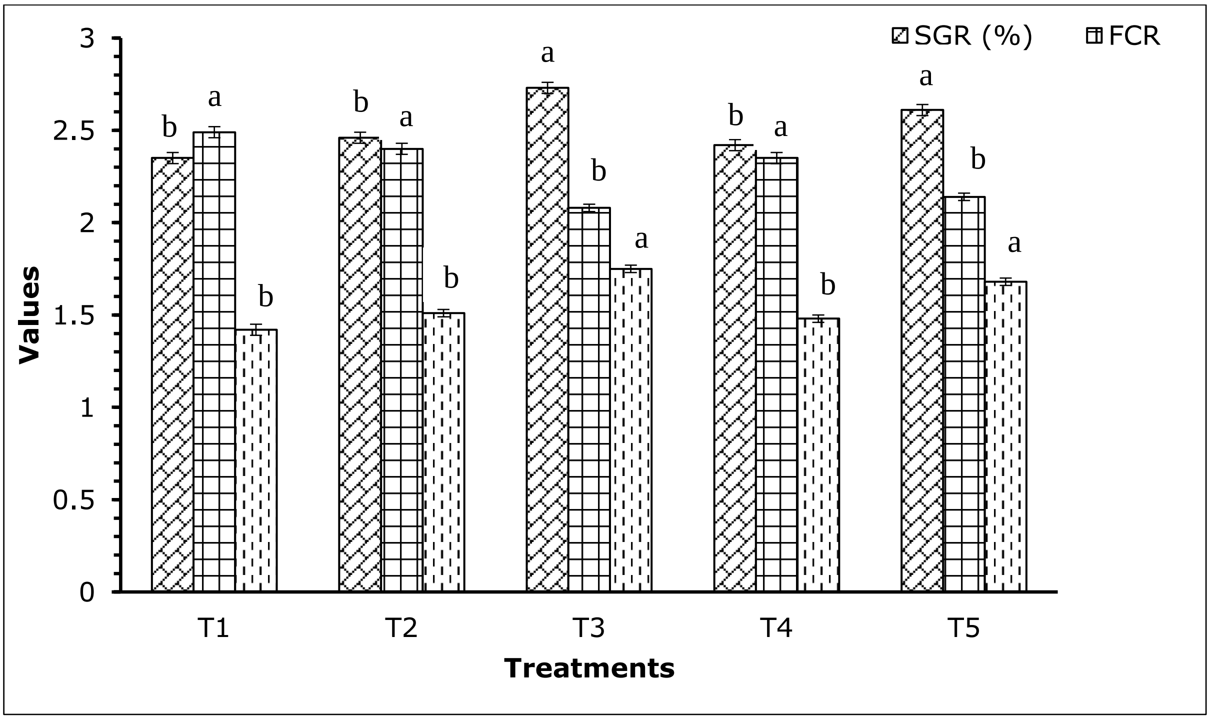

Figure 3. The SGR, FCR and PER of stinging catfish fed four treatments of fresh maggot, and a control diet. Different alphabet between columns indicated significant at $p<0.05$.

The apparent protein utilization (APU) rate of stinging catfish fed with live maggot T3 (85%) and T5 (82%) formulation was found significantly higher (p<0.05) amongst the treatments, followed by T2 (77%), and T1, T4 (76%). On the other hand, the survival rate of stinging catfish fed with T3 (89%) formulation was found significantly highest (p<0.05), followed by T5 (83%), T4 (82%), T1 (79%), and T2 (78%) (Figure 4).

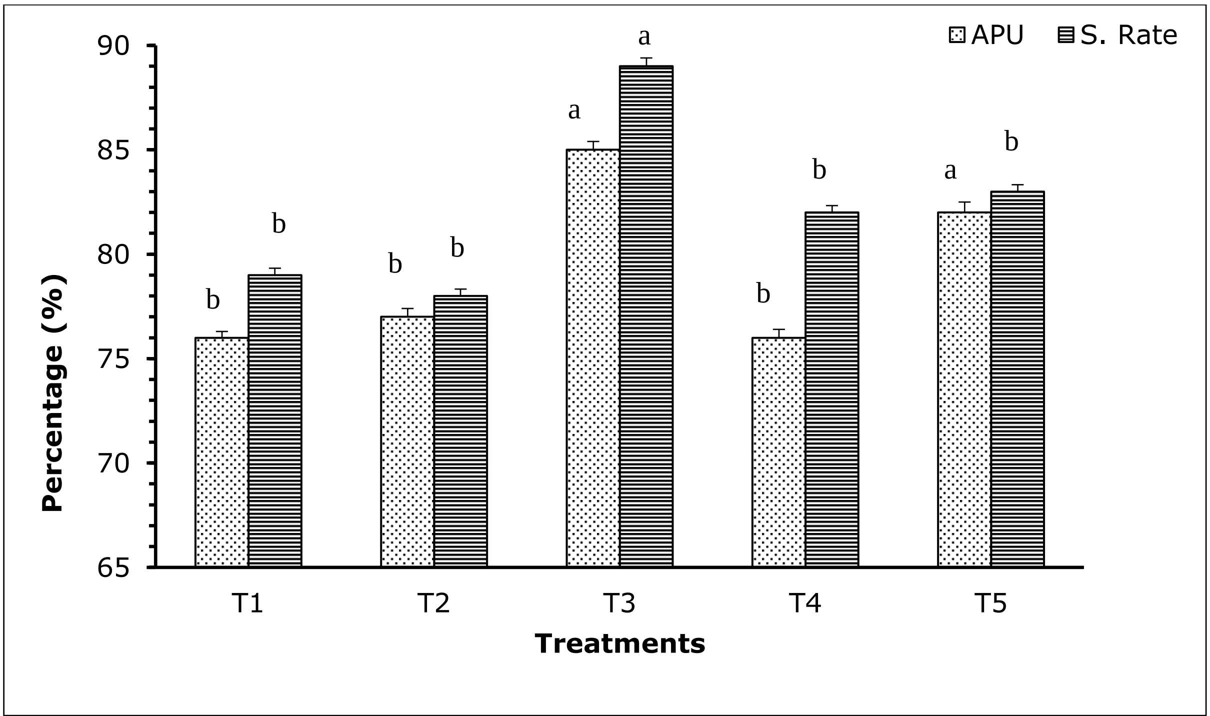

Figure 4. The APU and survival rate (S. Rate) of stinging catfish fed four different diets of fresh maggot, and a control diet. Different alphabet letter between columns indicated significant differences at p<0.05.

The carcass composition of stinging catfish post-larvae fed with live maggot T3 formulation showed the significantly highest (*p*<0.05) protein value (63.50±1.13%) and less amount of lipid (12.60±0.03%) and ash (10.65±0.03%) percentage than that of other treatments. No significant difference was observed in moisture content and NFE values amongst the treatments (Table 8).

Table 5

Carcass composition of stinging catfish post-larvae fed four different diets prepared with live maggot, and a control diet

Proximate (%)	*Initial*	*T1*	*T2*	*T3*	*T4*	*T5*
Moisture	9.90±0.02	9.80±0.02[a]	9.85±0.02[a]	9.80±0.02[a]	9.95±0.02[a]	9.80±0.02[a]
Protein	45.20±0.75	58.15±1.12[b]	59.80±1.12[b]	63.50±1.13[a]	60.30±1.10[b]	59.10±1.10[b]
Lipid	8.75±0.03	14.73±0.03[a]	14.45±0.03[a]	12.60±0.03[ab]	14.10±0.03[a]	15.30±0.04[a]
Ash	26.05±0.24	12.85±0.03[a]	12.30±0.03[a]	10.65±0.03[b]	11.90±0.03[a]	12.20±0.03[a]
NFE	9.70±0.03	4.42±0.03[a]	3.55±0.03[a]	3.30±0.03[a]	3.70±0.03[a]	3.55±0.03[a]

Note: Different alphabet letter between columns indicated significant differences at p<0.05.

Post-larval production of stinging catfish using maggot meal

Proximate composition of maggot meal and fish meal formulation. The moisture content of maggot meal and fish meal formulation for stinging catfish post-larval production ranged between 10.50±0.04 and 10.75±0.04%, while the crude protein ranged between 29.60±0.30% and 29.80±0.30% with no significant difference (p>0.05). On the other hand, crude lipid ranged between 10.10±0.02 and 10.25±0.02%, while the ash content ranged between 12.30±0.02% and 12.50±0.02% with no significant difference (p>0.05).

Lastly, the crude fiber and the NFE ranged between 5.70±0.02% and 12.85±0.02% and 24.16±0.14% and 31.30±0.17% respectively with no significant difference ($p>0.05$) (Table 9).

Table 9

Proximate composition (%) of four isonitrogenous formulated diets prepared with maggot meal, and a control diet for stinging catfish post-larval production

Components (%)	*T1*	*T2*	*T3*	*T4*	*T5*
Moisture	10.50±0.04^{a}	10.75±0.04^{a}	10.70±0.04^{a}	10.60±0.04^{a}	10.75±0.04^{a}
Crude protein	29.70±0.35^{a}	29.80±0.30^{a}	29.60±0.30^{a}	29.70±0.40^{a}	29.70±0.32^{a}
Crude lipid	10.15±0.02^{a}	10.25±0.02^{a}	10.10±0.02^{a}	10.20±0.02^{a}	10.18±0.02^{a}
Ash content	12.50±0.02^{a}	12.34±0.02^{a}	12.40±0.02^{a}	12.45±0.02^{a}	12.30±0.02^{a}
Crude fiber	9.50±0.02^{a}	7.85±0.02^{a}	6.60±0.02^{a}	5.70±0.02^{a}	12.85±0.02^{a}
NFE	27.60±0.15^{a}	28.95±0.13^{a}	30.54±0.16^{a}	31.30±0.17^{a}	24.16±0.14^{a}

Note: Different alphabet letter between columns indicated significant differences at $p<0.05$.

The maggot meal formulations T3 (1.61g) and T5 (1.51g) showed the significantly highest ($p<0.05$) final weight, followed by T2 (1.49 g), T1 (1.42 g) and T4 (1.19 g). On the other hand, T3 (1.418 g) and T5 (1.319 g) showed the significantly ($p<0.05$) highest weight gain during the experimental period, followed by T2 (1.30 g), T1 (1.229 g) and T4 (0.999 g) (Figure 5).

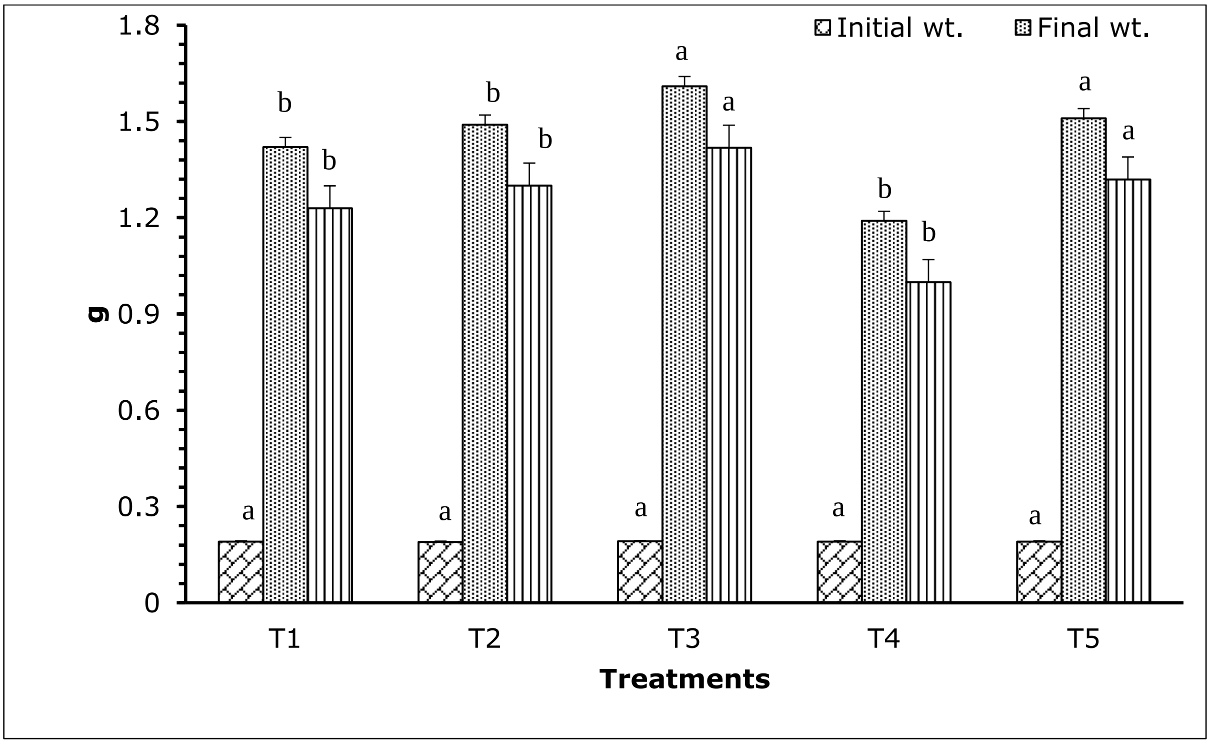

Figure 5. Initial weight, final weight and weight gain of stinging catfish fed four different diets prepared with different inclusion levels of maggot meal, and a control diet. Different alphabet letter between columns indicated significant at $p<0.05$.

The percentage of weight gain (%) was highest ($p<0.05$) in stinging catfish fed with maggot meal T3 (739±1.18%) formulation, followed by T5 (691±1.15%), T2 (655±1.14%), T1 (644±1.15%) and T4 (523±1.04%) (Table 6).

Table 6

Growth performances (Mean±SE) of stinging catfish (*H. fossilis*) post-larvae fed four different diets prepared with maggot meal, and a control diet

Growth parameters	*T1*	*T2*	*T3*	*T4*	*T5*
Weight gain (%)	644±1.15[b]	655±1.14[b]	739±1.18[a]	523±1.04[c]	691±1.15[a]

Note: Different alphabet letter between columns indicated significant differences at $p<0.05$.

The weekly growth trends of catfish post-larvae fed with T3 maggot meal formulation gave the highest growth trend amongst all the treatments; it reached 0.556g in the first week, 0.865g, 1.296g and 1.61g in the second, third and fourth week respectively. On the other hand, T4 showed the lowest growth trends amongst the treatment, while first week (0.502g), second week (0.822g), third week (1.241g) and fourth week (1.42g) showed the least growth (Figure 6).

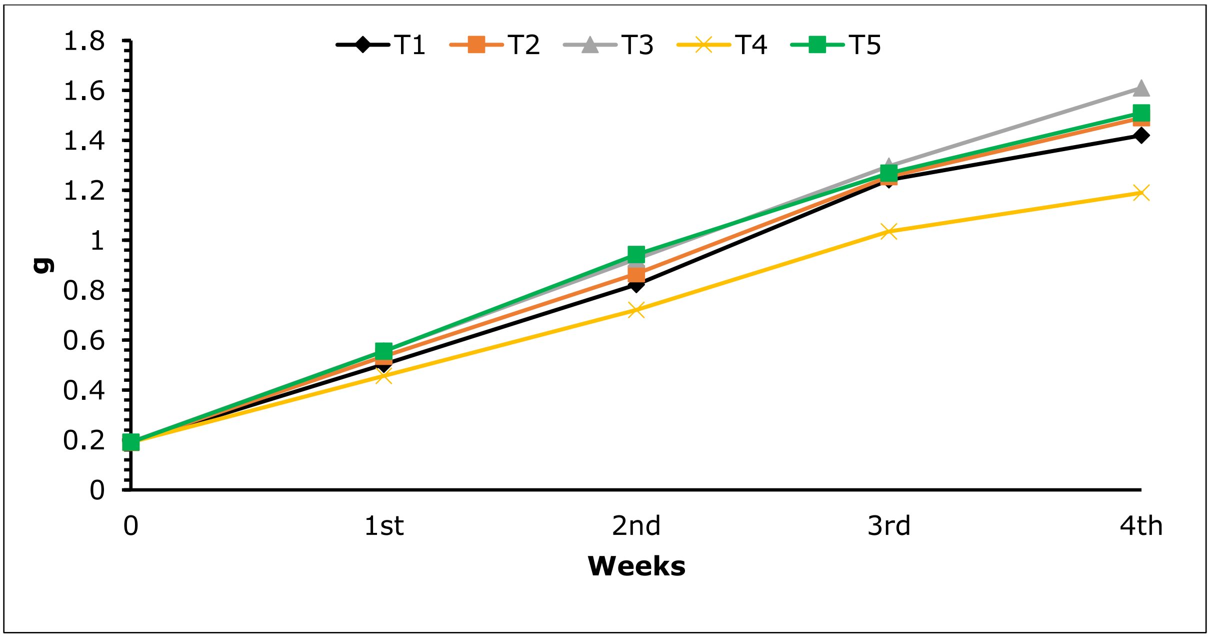

Figure 6. Weekly weight gain (g) of stinging catfish fed with maggot meal and fish meal formulation.

The SGR of catfish post-larvae fed with maggot meal T3 (2.63) and T5 (2.60) formulations were found significantly ($p<0.05$) highest amongst the treatments, followed by T1 (2.48), T2 (2.45) and T4 (2.42) while the FCR of T3 (2.06) significantly lowest followed by T2 (2.25), T1 (2.35), T4 (2.45), and T5 (2.46). On the other hand, T3 (2.29) showed the significantly highest PER amongst the treatments followed by T2 (2.04), T1 (1.85), T5 (1.67) and T4 (1.49) (Figure 7).

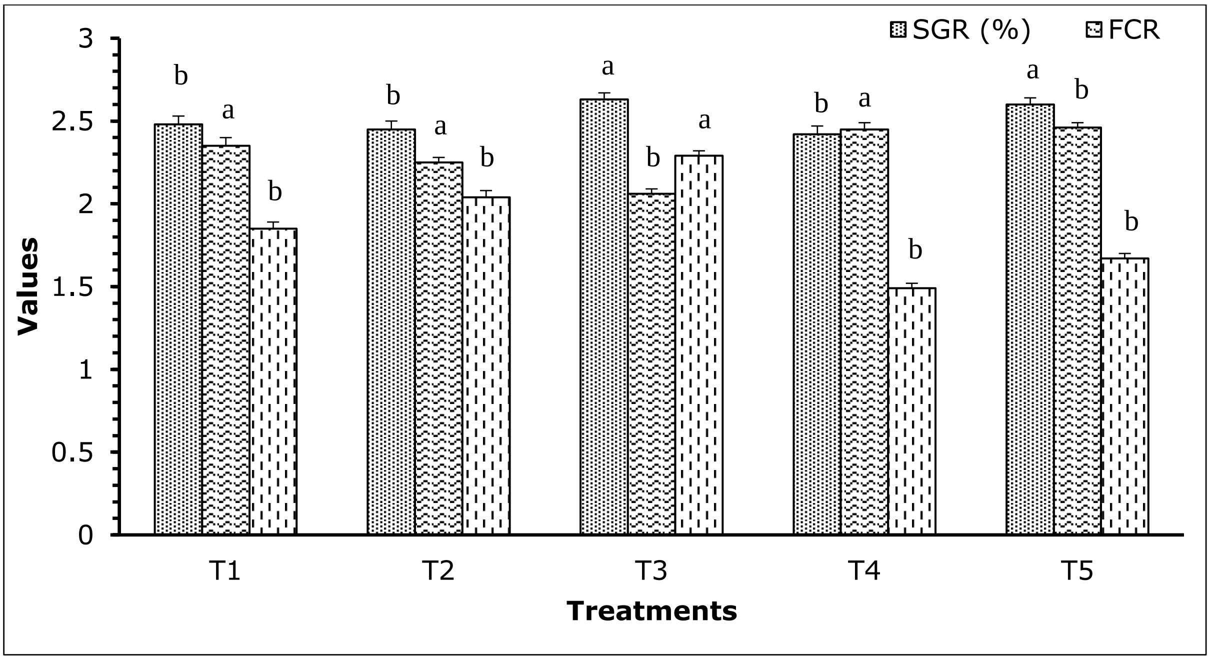

Figure 7. The SGR, FCR PER of stinging catfish fed maggot meal, and a control diet. Different alphabet letter between columns indicated significant differences at p<0.05.

The APU rate of stinging catfish fed with maggot meal T3 (85%) and T5 (81%) formulations were found significantly higher (p<0.05) amongst the treatments, followed by T4 (78%), T2 (76%), and T1 (75%). Similarly, the survival rate of stinging catfish fed with maggot meal T3 (90%) and T5 (85%) formulations were found to be significantly higher (p<0.05), followed by T2 (83%), T4 (82%), and T1 (81%) (Figure 8).

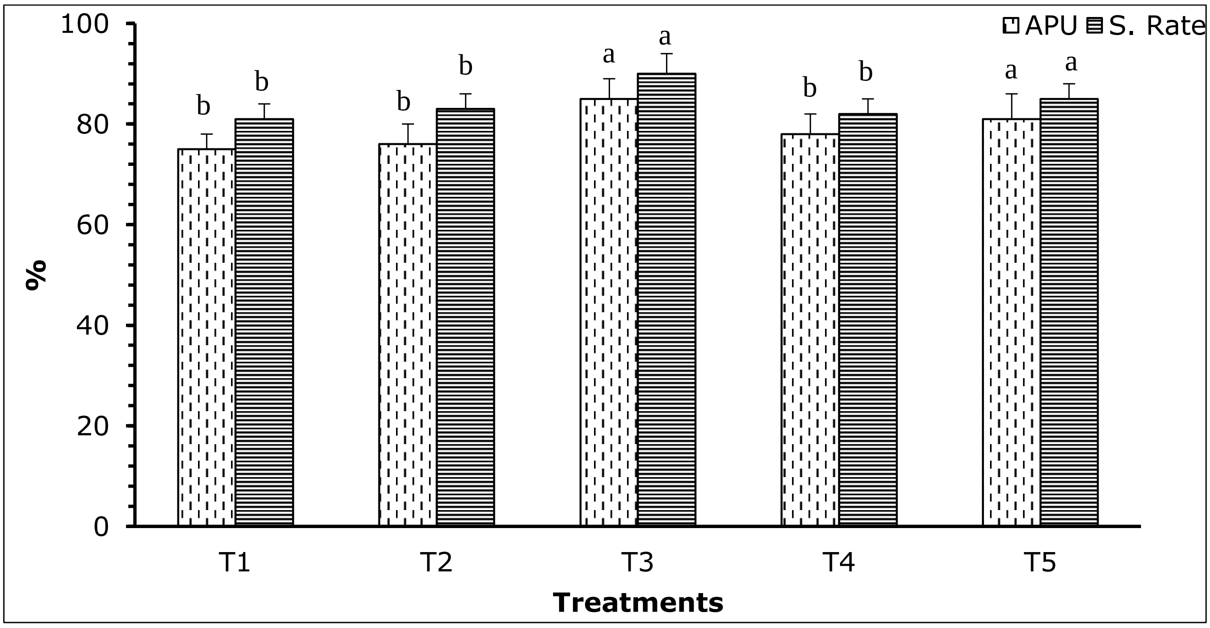

Figure 8. The APU and survival rate (S. Rate) of stinging catfish fed with maggot meal and fish meal. Different alphabet letter between columns indicated significant differences at p<0.05.

The carcass composition of stinging catfish post-larvae fed with maggot meal T3 formulation showed the significantly higher (p<0.05) protein value (62.10±0.50%) whereas a less value of NFE (3.85±0.03) was observed. No significant differences were observed in moisture content, crude lipid, and ash content percentage amongst the treatments (Table 7).

Table 7
Carcass composition of stinging catfish post-larvae fed with maggot meal and fish meal formulation

Components (%)	*T1*	*T2*	*T3*	*T4*	*T5*
Moisture	10.20±0.04[a]	10.25±0.04[a]	10.30±0.04[a]	10.20±0.03[a]	10.15±0.03[a]
Crude protein	58.30±0.55[b]	59.50±0.65[b]	62.10±0.50[a]	60.20±0.50[b]	58.40±0.50[b]
Crude lipid	12.15±0.03[a]	12.25±0.03[a]	12.50±0.04[a]	11.10±0.03[a]	12.80±0.04[a]
Ash content	13.50±0.04[a]	12.50±0.03[a]	11.20±0.03[a]	12.70±0.03[a]	13.60±0.04[a]
NFE	5.80±0.03[a]	5.45±0.03[a]	3.85±0.03[b]	5.75±0.03[a]	5.00±0.03[b]

Note: Different alphabet letter between columns indicated significant differences at $p<0.05$.

Discussion. The use of live common green bottle fly (*Lucilia sericata*) maggot as protein source and maggot meal as the fish meal replacer in the production of the stinging catfish, *Heteropneustes fossilis* were the main goals of this research. The fly larvae comprised high protein, 56.60±0.25%, lipids 15.80±0.10% and ash content 15.40±0.07%, revealing the potentiality of the maggot as feed material, especially as the protein source for human or cultured animal (Odesanya et al 2011; Papuc et al 2020). Available literature shows that the price of protein feed is found always high in the market and considered one of the greatest challenges for reducing the price of the aquaculture final product (Dickson et al 2016; Fry et al 2018; Hua et al 2019; Hyuha et al 2011). Despite the many different sources of protein, most of them require culturing in farm and high maintenance standard, hence the impetus to seek for a cheap yet good standard protein source, presenting fly larvae as the most inexpensive, low maintenance production and good quality protein source (Al-Thobaiti et al 2018; Chen et al 2019; Egerton et al 2020; Tippayadara et al 2021).

With a 0.192±0.01 g to 0.193±0.01 g initial weight and 28 days of post-larval rearing, *H. fossilis* showed higher final weight (1.55 g), weight gain (1.356 g), percentage of weight gain (699±1.50%), specific growth rate (2.73), protein efficiency ratio (1.75), apparent protein utilization (85%), survival rate (89%) and lower food conversion ratio (2.08) in the treatment fed with 60 live maggots. The weekly trends of growth rate in treatments fed with 60 live maggots fed for *H. fossilis* post-larval production found highest. Some previous study suggested that, the catfishes showed higher growth rate and other growth parameters when fed on fresh or frozen maggot (Devic et al 2018; Djissou et al 2016; Okore et al 2016; Saleh 2020). In nature, *H. fossilis* was found to be a carnivorous and predatory fish species feeding on insects and crustaceans (Narejo et al 2016); creating the natural habitat condition and providing the live feed might stimulate *H. fossilis* growth rate. The treatments of providing maggot classified according to ascending manner were aimed at investigating which treatment show the significantly highest result. Protein efficiency ratio (PER) was found to be one of the most significant indexes for determining how much protein was consumed throughout the trial period; this ratio is useful in determining whether one protein source should be replaced with another in catfish aquaculture (Enyidi et al 2017; Farhat & Khan 2011; Keremah & Alfred-Ockiya 2013; Kim et al 2014; Sánchez et al 2009). The feed conversion ratio of the live maggot was found comparatively higher than that of the commercial feed, moreover the live maggot was cheaper to obtain and the production requires less maintenance, making the overall benefit for use of live maggot in producing *H. fossilis* post larvae profitable for the aquaculture operation (Bosma et al 2017; Olaniyi & Salau 2013). Whereas the study of Aniebo et al (2009) found lower FCR while replacing fish meal with maggot meal in African catfish (*Clarias gariepinus*), the protein requirement and other factors of the current experimental fish and *C. gariepinus* are not similar. Observing growth criteria and other investigated parameters in the current study, feeding *H. fossilis* with 60 maggots during the post-larval culture can be suggested the best for growth and aquaculture system.

This study also observed the growth rate of *H. fossilis* post-larvae using maggot meal as a replacer of fish meal; the values and concentration of moisture, crude protein, crude lipids, ash content, crude fiber, and nitrogen free extract were found similar in proximate analysis. In order to properly create an experimental diet, it is vitally required to know the approximate composition of such a diet, while the method was to substitute one protein source for another (Bhaskar et al 2015; Hua et al 2019; Jahan et al 2021; Mdhluvu et al 2021). Growth rates in treatments fed with 75% maggot meal for raising *H. fossilis* post-larval production were determined to be the fastest on a weekly basis among all the other experimented treatments. The post-larval, fingerling and production of different catfish species using maggot meal as a replacer of fish meal showed similar result (Aniebo et al 2009; Djissou et al 2016; Fasakin et al 2003); however no study on the presented species could be found to enable comparison with present results.

The carcass composition of stinging catfish post-larvae fed with 60 live maggots showed the significantly highest protein value of 63.50±1.13%. On the other hand the carcass composition of post-larvae fed with 75% maggot meal showed the significantly highest protein value of 62.10±0.50%. The study of Majhi and Das (2014) showed the protein composition of *H. fossilis* carcass might reach up to 46.97±0.9%; the afore-mentioned author considered 60 days for measuring the proximate composition of the carcass whereas the present study considered 28 rearing days and fish age difference might be a factor for changing the protein percentage of the carcass. However a 56 days trial on different isocaloric and protein composition of another study showed far less protein content (15.76±0.15%) in the final product carcass of *H. fossilis*, which might be the result of less protein in feed, types of feed, and age of fish (Siddiqui & Khan 2009).

Conclusions. The stinging catfish, *Heteropneustes fossilis* post-larval feed with 60 maggots and 75% maggot meal as a fish meal replacer showed the best result in the current experiment. It is recommended to use the live maggot and maggot meal as a protein source and fish meal replacer, which will be cheaper, yet profitable to the aquaculture business.

Acknowledgements. We would like to extend our gratitude to Department of Aquaculture and Department of Animal Nutrition, Bangladesh Agricultural University, for providing the technical and logistic supports. The research team also acknowledges the fund from Ministry of Higher Education Malaysia, FRGS research grant code, FRGS/1/2018/WAB13/UPM/02/2, Vot. No. 07-01-18-2044.

Conflict of interest. The authors declare that there is no conflict of interest.

References

Abdel-Raouf N., Al-Homaidan A. A., Ibraheem, I. B. M., 2012 Microalgae and wastewater treatment. Saudi Journal of Biological Sciences 19:257–275.

Alam R., Hossain M. D., 2009 Wastewater quality of natural gas fertilizer factory, Fenchuganj and water quality of Kushiara River at the down stream. Environmental Monitoring and Assessment 154:127–133.

Alfiko Y., Xie D., Astuti R. T., Wong J., Wang L., 2021 Insects as a feed ingredient for fish culture: Status and trends. Aquaculture and Fisheries 7:166–178.

Ali M., Al-Asif A., Shabuj A. I., Omar F., Vaumik S., Zafar A., Sharif B. M. N., 2016a Dose optimization with synthetic hormone flash for induced spawning of Shing (*Heteropneustes fossilis*). International Journal of Fauna and Biological Studies 3:39–45.

Ali M. M., Al-Asif A., Shabuj A. I., Faruq O., Vaumik S., Sharif B. M. N., Zafar M. A., 2016b Technology of artificial breeding of catfish species in the hatcheries in Jessore region, Bangladesh. International Journal of Fisheries and Aquatic Studies 4:180–188.

Al-Thobaiti A., Al-Ghanim K., Ahmed Z., Suliman E. M., Mahboob S., 2018 Impact of replacing fish meal by a mixture of different plant protein sources on the growth performance in nile tilapia (*Oreochromis niloticus* L.) diets. Brazilian Journal of Biology 78:525–534.

Aniebo A. O., Erondu E. S., Owen O. J., 2009 Replacement of fish meal with maggot meal in african catfish (*Clarias gariepinus*) diets. Revista Cientifica UDO Agricola 9:666–671.

Anwar M. F., Jafri A. K., 1995 Effect of varying dietary lipid levels on growth, feed

conversion, nutrient retention and carcass composition of fingerling catfish, *Heteropneustes fossilis*. Asian Fisheries Science 8:55–62.
Austreng E., 1978 Digestibility determination in fish using chromic oxide marking and analysis of contents from different segments of the gastrointestinal tract. Aquaculture 13:265–272.
Ayilara M. S., Olanrewaju O. S., Babalola O. O., Odeyemi O., 2020 Waste management through composting: Challenges and potentials. Sustainability 12:1–23.
Bezbaruah G., Deka D. D., 2021 Variation of moisture and protein content in the muscle of three catfishes: A comparative study. International Journal of Fisheries and Aquatic Studies 9:223–226.
Bhaskar P., Pyne S. K., Ray A. K., 2015 Growth performance study of Koi fish, *Anabas testudineus* (Bloch) by utilization of poultry viscera, as a potential fish feed ingredient, replacing fishmeal. International Journal of Recycling of Organic Waste in Agriculture 4:31–37.
Bhattacharjee I, Chandra G., 2016 Food and feeding habits of three air-breathing fish in its natural habitat. International Journal of Fisheries and Aquatic Studies 4:586–589.
Bhattacharjee I., Aditya G., Chandra G., 2009 Laboratory and field assessment of the potential of larvivorous, air-breathing fishes as predators of culicine mosquitoes. Biological Control 49:126–133.
Billah M. M., Uddin M. K., Samad M. Y. A., Hassan M. Z. B., Anwar M. P., Abu Hena M. K., Shahjahan M., Al-Asif A., 2019 Effects of different stocking density of Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) on the growth performance and rice yield in rice-fish farming system. AACL Bioflux 13:789–803.
Boaru A., Vig A., Ladoşi D., Struţi D., Păpuc T., Georgescu B., 2018 Studies regarding the fertilizing capacity of poultry manure biocomposted by fly larvae (Diptera: Stratiomyidae). AAB Bioflux 10(3):114-121.
Bosma R. H., Lacambra L., Landstra Y., Perini C., Poulie J., Schwaner M. J., Yin Y., 2017 The financial feasibility of producing fish and vegetables through aquaponics. Aquacultural Engineering 78:146–154.
Cammack J. A., Tomberlin J. K., 2017 The impact of diet protein and carbohydrate on select life-history traits of the black soldier fly *Hermetia illucens* (L.) (Diptera: Stratiomyidae). Insects 8:1–14.
Cashion T., Le Manach F., Zeller D., Pauly D., 2017 Most fish destined for fishmeal production are food-grade fish. Fish and Fisheries 18:837–844.
Chen Y., Ma J., Huang H., Zhong H., 2019 Effects of the replacement of fishmeal by soy protein concentrate on growth performance, apparent digestibility, and retention of protein and amino acid in juvenile pearl gentian grouper. PLoS ONE 14:e0222780.
Choi W., Hamidoghli A., Bae J., Won S., Choi Y. H., Kim K. W., Lee B. J., Hur S. W., Han H., Bai S. C., 2020 On-farm evaluation of dietary animal and plant proteins to replace fishmeal in sub-adult olive flounder *Paralichthys olivaceus*. Fisheries and Aquatic Sciences 23:1–8.
Das P. C., Mandal S., Mandal B., 2021 Intensive culture of Asian stinging cat fish *Heteropneustes fossilis* (Bloch, 1794) in the biofloc system: An attempt towards freshwater conservation. International Journal of Fisheries and Aquatic Studies 9:194–199.
Devic E., Leschen W., Murray F., Little D. C., 2018 Growth performance, feed utilization and body composition of advanced nursing Nile tilapia (*Oreochromis niloticus*) fed diets containing Black Soldier Fly (*Hermetia illucens*) larvae meal. Aquaculture Nutrition 24:416–423. W
Dickson M., Nasr-Allah A., Kenawy D., Kruijssen F. 2016 Increasing fish farm profitability through aquaculture best management practice training in Egypt. Aquaculture 465: 172–178.
Djissou A. S. M., Adjahouinou D. C., Koshio S., Fiogbe E. D., 2016 Complete replacement of fish meal by other animal protein sources on growth performance of *Clarias gariepinus* fingerlings. International Aquatic Research 8:333–341.
Egerton S., Wan A., Murphy K., Collins F., Ahern G., Sugrue I., Busca K., Egan F., Muller N., Whooley J., McGinnity P., Culloty S., Ross R. P., Stanton C., 2020 Replacing

fishmeal with plant protein in Atlantic salmon (*Salmo salar*) diets by supplementation with fish protein hydrolysate. Scientific Reports 10:1–16.
Enyidi U. D., Pirhonen J., Kettunen J., Vielma J., 2017 Effect of feed protein:Lipid ratio on growth parameters of african catfish *Clarias gariepinus* after fish meal substitution in the diet with bambaranut (*Voandzeia subterranea*) meal and soybean (*glycine max*) meal. Fishes 2:1–11.
Farhat, Khan M. A., 2011 Growth, feed conversion, and nutrient retention efficiency of African catfish, *Clarias gariepinus*, (Burchell) fingerling fed diets with varying levels of protein. Journal of Applied Aquaculture 23:304–316.
Faruk A., Hossain A., Al-Asif A., Bhuiyan M. N. M., Sarker M. J., 2018 Culture and management techniques of Vietnamese Koi. Asian-Australasian Journal of Bioscience and Biotechnology 3:93–105.
Fasakin E. A., Balogun A. M., Ajayi O. O., 2003 Evaluation of full-fat and defatted maggot meals in the feeding of clariid catfish *Clarias gariepinus* fingerlings. Aquaculture Research 34:733–738.
Fatma S., Ahmed I., 2020 Effect of water temperature on protein requirement of *Heteropneustes fossilis* (Bloch) fry as determined by nutrient deposition, hemato-biochemical parameters and stress resistance response. Fisheries and Aquatic Sciences 23:1–14.
Fernandez F., Miquel A. G., Martinez R., Serra E., Guinea J., Narbaiza F. J., Caseras A., Baanante I. V., 1999 Dietary chromic oxide does not affect the utilization of organic compounds but can alter the utilization of mineral salts in Gilthead sea bream *Sparus aurata*. Journal of Nutrition 129:1053–1059.
Firoozfar F., Moosa-Kazemi H., Baniardalani M., Abolhassani M., Khoobdel M., Rafinejd J., 2011 Mass rearing of *Lucilia sericata* Meigen (Diptera: Calliphoridae). Asian Pacific Journal of Tropical Biomedicine 1:54–56.
Fry J. P., Mailloux N. A., Love D. C., Milli M. C., Cao L., 2018 Feed conversion efficiency in aquaculture: Do we measure it correctly? Environmental Research Letters 13:024017.
Furukawa A., Hiroko T., 1966 On the acid digestion method for determination of chromic oxide as an indicator substance in the study of digestibility in fish. Bullentin of the Japanese Society of Scientific Fisheries 32:502–506.
Gałęcki R., Zielonka Ł., Zasępa M., Gołębiowska J., Bakuła T., 2021 Potential utilization of edible insects as an alternative source of protein in animal diets in Poland. Frontiers in Sustainable Food Systems 5:675796.
Glatz P., Miao Z., Rodda B., 2011 Handling and treatment of poultry hatchery waste: A review. Sustainability 3:216–237.
Gold M., Cassar C. M., Zurbrügg C., Kreuzer M., Boulos S., Diener S., Mathys A., 2020 Biowaste treatment with black soldier fly larvae: Increasing performance through the formulation of biowastes based on protein and carbohydrates. Waste Management 102:319–329.
Habib M. A. B., Ullah M. S., Hasan M. R., Hossain M. S., 2001 Use of silkworm pupae as partial replacement of fishmeal in the diets with rotifer as feed additive of Asian catfish, *Clarias batrachus* (Linn.) fry. Bangladesh Journal of Fisheries 24:133–141.
Habib M. A. B., Yusoff F. M., Phang S. M., Mohamed S., 2005 Experimental production and chemical composition of Culex mosquito larvae and pupae grown in agro-industrial effluent. Asian Fisheries Science 18:107–119.
Hamli H., Hossain A., Ahmed S., Al-Asif A., Rashid M. H., Rahman H., 2021 Biochemical, mineral compositions and microbial assessment of smoked hilsa (*Tenualosa ilisha*) with leaves, juice, and lemon peel. AACL Bioflux 14:2241–2251.
Haniffa M. A., Sridhar S., Nagarajan M., 2004 Hormonal manipulation of sex in stinging catfish *Heteropneustes fossilis* (Bloch). Current Science 86:1012–1017.
Hasan M. R., Hossain M. Y., Mawa Z., Hossain M. A. R., 2022 Reproductive biology of *Heteropneustes fossilis* in a wetland ecosystem (Gajner Beel, Bangladesh) in relation to eco-climatic factors: Suggesting a sustainable policy for aquaculture, management and conservation. Saudi Journal of Biological Sciences 29(2):1160-1174.
Hasnol S., Kiatkittipong K., Kiatkittipong W., Wong C. Y., Khe C. S., Lam M. K., Show P.

L., Oh W. D., Chew T. L., Lim J. W., 2020 A review on insights for green production of unconventional protein and energy sources derived from the larval biomass of black soldier fly. Processes 8:523.
Holloway B. A., 1991 Morphological characters to identify adult *Lucilia sericata* (Meigen, 1826) and *L. cuprina* (wiedemann, 1830) (Diptera: Calliphoridae). New Zealand Journal of Zoology 18:413–420.
Hua K., Cobcroft J. M., Cole A., Condon K., Jerry D. R., Mangott A., Praeger C., Vucko M. J., Zeng C., Zenger K., Strugnell J. M., 2019 The future of aquatic protein: Implications for protein sources in aquaculture diets. One Earth 1:316–329.
Hyuha T. S., Bukenya J. O., Twinamasiko J., Molnar J., 2011 Profitability analysis of small scale aquaculture enterprises in central Uganda. International Journal of Fisheries and Aquaculture 3:271–278.
Islam M. A., Samad M. A., Paul D., Asif A. Al, Hossain A., 2021 Feeding frequency on the growth and production of endemic near-threatened *Ompok pabda* (Hamilton 1822) in pond setup. Asian-Australasian Journal of Bioscience and Biotechnology 6:89–102.
Izzah N., Abdul H., Hanafiah M. M., Halim N. H., 2020 Phytoremediation of TSS, NH_3-N and COD from sewage wastewater by *Lemna minor* L., *Salvinia minima*, *Ipomea aquatica* and *Centella asiatica*. Applied Sciences 10:1–12.
Jahan H., Tumpa I. J., Qasem W. A., Moniruzzaman M., Pervin M. A., Akter R., Omri A., Min T., Hossain Z., 2021 Evaluation of the partial replacement of dietary Fish meal With fermented or untreated soybean meal in juvenile silver barb, *Barbonymus gonionotus*. Frontiers in Nutrition 8:733402.
Keremah R. I., Alfred-Ockiya J. F., 2013 Effects of dietary protein level on growth and body composition of mudfish, *Heterobranchus longifilis* fingerlings. African Journal of Biotechnology 12:971–975.
Kim K. D., Kim K. W., Lee B. J., Son M. H., Han H. S., Kim J. D., 2014 Dietary protein requirement for young far eastern catfish *Silurus asotus*. Fisheries and Aquatic Sciences 17:455–459.
Kwon G., Nam J. H., Kim D. M., Song C., Jahng D., 2020 Growth and nutrient removal of *Chlorella vulgaris* in ammonia-reduced raw and anaerobically-digested piggery wastewaters. Environmental Engineering Research 25:135–146.
Lange K. W., Nakamura Y., 2021 Edible insects as future food: chances and challenges. Journal of Future Foods 1:38–46.
Majhi S. K., Das S. K., 2014 Feed utilization, gonadal maturation, carcass composition and stress of the catfish, *Heteropneustes fossilis* (Bloch) fed with animal viscera-based diets at varied temperatures. Proceedings of the National Academy of Sciences India Section B - Biological Sciences 84:83–89.
Markou G., Wang L., Ye J., Unc A., 2018 Using agro-industrial wastes for the cultivation of microalgae and duckweeds: Contamination risks and biomass safety concerns. Biotechnology Advances 36:1238–1254.
Mazza L., Xiao X., Rehman K., Cai M., Zhang D., Fasulo S., Tomberlin J. K., Zheng L., Soomro A. A., Yu Z., Zhang J., 2020 Management of chicken manure using black soldier fly (Diptera: Stratiomyidae) larvae assisted by companion bacteria. Waste Management 102:312–318.
Mdhluvu R. M., Mlambo V., Madibana M. J., Mwanza M., O'Brien G., 2021 Crocodile meat meal as a fishmeal substitute in juvenile dusky kob (*Argyrosomus japonicus*) diets: Feed utilization, growth performance, blood parameters, and tissue nutrient composition. Aquaculture Reports 21:100779.
Melo R. G., Andrade A. F., Bezerra R. P., Correia D. S., Souza V. C., Brasileiro-Vidal A. C., Viana Marques D. A., Porto A. L. F., 2018 *Chlorella vulgaris* mixotrophic growth enhanced biomass productivity and reduced toxicity from agro-industrial by-products. Chemosphere 204:344–350.
Modak M., Chowdhury E. H., Rahman M. S., Sattar M. N., 2019 Waste management practices and profitability analysis of poultry farming in Mymensingh district: A socioeconomic study. Journal of the Bangladesh Agricultural University 17:50–57.
Narejo N. T., Jalbani S., Khan P., Memon F., 2016 Food and feeding habits of sting catfish, *Heteropneustes Fossilis* (Bloch) from Manchar lake district Jamshoro Sindh Pakistan.

Sindh University Research Journal 48:473–476.
Nogales-Mérida S., Gobbi P., Józefiak D., Mazurkiewicz J., Dudek K., Rawski M., Kierończyk B., Józefiak A., 2019 Insect meals in fish nutrition. Reviews in Aquaculture 11:1080–1103.
Nugroho R. A., Nur F. M., 2018 Insect-based protein: Future promising protein source for fish cultured. IOP Conference Series: Earth and Environmental Science 144:012002.
Odesanya B. O., Ajayi S. O., Agbaogun B. K. O., Okuneye B., 2011 Comparative evaluation of nutritive value of maggots. International Journal of Scientific and Engineering Research 2:1–5.
Okore O. O., Ekedo C. M., Ubiaru P. C., Uzodinma K., 2016 Growth and haematological studies of African catfish (*Clarias gariepinus*) juveniles fed with housefly larva (*Musca dometica*) as feed supplement. International Journal of Agriculture and Earth Science 2:21–30.
Olaniyi C. O., Salau B. R., 2013 Utilization of maggot meal in the nutrition of African cat fish. African Journal of Agricultural Research 8:4604–4607.
Papuc T., Boaru A., Ladosi D., Struti D., Georgescu B., 2020 Potential of black soldier fly (*Hermetia illucens*) as alternative protein source in Salmonid feeds - A review. Indian Journal of Fisheries 67:160–170.
Parry N. J., Pieterse E., Weldon C. W., 2020 Stocking rate and organic waste type affect development of three *Chrysomya* species and *Lucilia sericata* (Diptera: Calliphoridae): Implications for bioconversion. Journal of Applied Entomology 144:94–108.
Rahman M. M., Hossain M. Y., Hossain M. I., Jaman S., Islam M. S., Hossain M. B., 2013 Induced breeding of the stinging catfish, *Heteropneustes fossilis*: Comparison among different inducing agents. Turkish Journal of Fisheries and Aquatic Sciences 16:523–527.
Reza S. M. S., Islam S., 2019 Utilization potential of waste from sugarcane factory of Bangladesh as partial replacement of cement in concrete. Journal of Environmental Treatment Techniques 7:109–112.
Saleh H. H. E., 2020 Effect of feeding on fresh (wet) housefly maggots (*Musca domestica*) with or without artificial diet on water quality and growth rates of African catfish (*Clarias gariepinus* Burchell, 1822) fry under laboratory conditions. Journal of Zoological Research 2:15–22.
Salma U., Suraiy S., Isra L., Haq M., 2021 Biochemical and organoleptic assessment of Asian stinging catfish (*Heteropnuestes fossilis*) in two storage conditions. Asian Food Science Journal 20:27–37.
Samad M., Bhuiyan A., 2017 Stocking density of threatened cat fish *Heteropneustes fossilis* (Bloch, 1792) in seasonal ponds of Rajshahi, Bangladesh. Bangladesh Journal of Scientific and Industrial Research 52:253–262.
Samad M.A., Ali M. I., Paul D., Islam S. M. A. 2011 An environmental impact study of Jamuna urea fertilizer factory at Tarakandi in Jamalpur with radiological indices. Journal of Environmental Science and Natural Resources 4:27–33.
Samad M. A., Nahiduzzama M., Ashrafuzzaman M., Rashid M. A., Akter M. 2017 Culture of indigenous catfish Shingi, *Heteropneustes fossilis* (Bloch, 1794), with available low cost formulated feed in earthen ponds of Bangladesh. Journal of Coastal Life Medicine 5:288–292.
Sánchez J. A. M., Moyetones F., Cerdá M. J., 2009 Effect of dietary protein level on growth performance of fingerlings of catfish yaque, *Leiarius marmoratus*, fed with three commercial diets. Zootecnia Tropical 27:187–194.
Siddiqui T. Q., Khan M. A. 2009 Effects of dietary protein levels on growth, feed utilization, protein retention efficiency and body composition of young *Heteropneustes fossilis* (Bloch). Fish Physiology and Biochemistry 35:479–488.
Su M., Dell'Orto M., Scaglia B., D'Imporzano G., Bani A., Adani F., 2022 Growth performance, biochemical vomposition and nutrients recovery ability of twelve microalgae consortia isolated from various local organic wastes grown on nano-filtered pig slurry. Molecules 27:1–19.
Tacon A. G. J., Metian M., 2008 Global overview on the use of fish meal and fish oil in

industrially compounded aquafeeds: Trends and future prospects. Aquaculture 285:146–158.
Tippayadara N., Dawood M. A. O., Krutmuang P., Hoeseinifar S. H., Van Doan H., Paolucci M., 2021 Replacement of fish meal by black soldier fly (*Hermetia illucens*) larvae meal: Effects on growth, haematology, and skin mucus immunity of Nile Tilapia, *Oreochromis niloticus*. Animals 11:193.
Tran G., Heuzé V., Makkar H. P. S., 2015 Insects in fish diets. Animal Frontiers 5:37–44.
Williams K. A., Villet M. H., 2014 Morphological identification of *Lucilia sericata*, *Lucilia cuprina* and their hybrids (Diptera, Calliphoridae). ZooKeys 85:69–85.
Yaseen D. A., Scholz M., 2019 Textile dye wastewater characteristics and constituents of synthetic effluents: a critical review. International Journal of Environmental Science and Technology 16:1193–1226.
Zafar A., 2020 Comparative growth performance assessment of Shing (*Heteropneustes fossilis*) feeding with prepared and commercial diet. Journal of Aquaculture and Marine Biology 9:10–13.
Zhang J., Zhang J., Li J., Tomerlin J. K., Xiao X., Rehman K., Cai M., Zheng L., Yu Z., 2021 Black soldier fly: A new vista for livestock and poultry manure management. Journal of Integrative Agriculture 20:1167–1179.
*** Association of Official Analytical Chemists (AOAC), 2005 Official methods of analysis. 18th edn. Association of Official Analytical Chemists; Arlington, VA, USA.
*** National Research Council (NRC), 1983 Nutritional requirement of warmwater fishes and shellfishes. National Academy of Sciences, Washington, D.C., USA.
*** SPSS 25, 2016 IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0 (25.0). IBM Corp.

Received: 06 February 2022. Accepted: 09 May 2022. Published online: 16 December 2022.
Authors:
Abdus Satter, Department of Fisheries, Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University, Melandah, Jamalpur-2012, Bangladesh, e-mail: satter@bsfmstu.ac.bd
Md. Ahsan Bin Habib, Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh, e-mail: ahsanmphd@yahoo.com
Abdulla-Al-Asif, Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia, e-mail: jessoreboyhemel@gmail.com
Hadi Hamli, Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia, e-mail: hadihamli@upm.edu.my
Amir Hossain, International Studies in Aquatic Tropical Ecology (ISATEC), Department of Biology, University of Bremen, Bibliothekstraße 1, 28359 Bremen, Germany, e-mail: amhnstu@gmail.com

How to cite this article:
Satter A., Habib M. A. B., Al-Asif A., Hamli H., Hossain A., 2022 Replacement of fish meal by *Lucilia sericata* (Meigen, 1826) live larvae and powdered meal in production of stinging catfish *Heteropneustes fossilis* (Bloch, 1794) post-larvae. AACL Bioflux 15(6):3220-3237.