Black soldier fly (*Hermetia illucens*) larvae meal as a fish meal replacement in diets for nursing common carp (*Cyprinus carpio*) fry

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Highlights

- Sustainable aquaculture needs an alternative to fishmeal due to its negative impact on health and industry.
- Black soldier fly larvae (BSFL) can be a suitable source of protein to replace fishmeal in diets.
- We found a total replacement of fishmeal with BSFL has remarkable effect on growth of common carp fry.

Abstract

Black soldier fly larvae (BSFL) meal-based diet is an innovative strategy for sustainable aquaculture. In the present study, black soldier fly larvae meal has shown a promising alternative as a fish meal (FM) replacement in diets for common carp fry. Black soldier fly larvae; a protein, fat and minerals containing non-pest insect, when used as fish feed ingredient minimize feed cost, boost up fish production and tackle environmental hazards. Five feeds were formulated where fish meal was replaced by BSF larvae for nursing of common carp fry. Feeds were prepared by 100 (T_1), 75 (T_2), 50 (T_3), 25 (T_4) and 0% (T_5) replacement of fish meal with BSF larvae as a protein and minerals supplement. Among the feeds T_3 performed better than T_1. Most of the common carp fry were healthy and robust in treatment T_1 and T_3 where %weight gain was 417.70% and 427.95%, respectively. The lower feed conversion ratio (FCR) was also obtained in treatment T_1 (3.54) and T_3 (3.42) whereas, higher FCR was found in T_4. However, at harvest, the highest fry production was obtained with T_1 (3.10 tons/ha/60 days) where 100% fish meal was replaced by BSF larvae. Therefore, 100% fish meal can be replaced by BSFL easily to address the protein scarcity, adulteration and environmental hazards.

Keywords: Black soldier fly larvae, Fish meal, Common carp fry, Feed conversion ratio, Growth

1. Introduction

Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world. World food fish consumption rose from 9.0 kg per capita (live weight equivalent) in 1961 to 20.3 kg in 2017 and preliminary estimates for per capita fish consumption in 2018 currently stand at 20.5 kg (FAO, 2020). Thanks to vigorous growth in aquaculture, which now provides half of all fish for human consumption, and to a slight improvement in the state of certain fish stocks due to improved fisheries management. Aquaculture is largely dependent on the availability of aqua feed that are primarily based on fishmeal. However, this reliance on wild fish capture for fish farming is under question in terms of profitability and environmental sustainability (Madibana et al., 2020) as it may contain contaminants such as polychlorinated biphenyls and dioxins (Naylor et al., 2009; Tran et al., 2015). Also, the volatility and rise of fish meal prices is a matter of concern for fish farmers (Olsen and Hasan, 2012). As a consequence, there has been an ongoing search for alternative sources of protein that would allow aquaculture to remain economically and environmentally sustainable (Barroso et al., 2014; Madibana *et al.*, 2020).

In the recent years, insects such as black soldier fly larvae have received wide attention as a potential source of protein both for humans and livestock. Insects grow and reproduce easily, have high feed conversion efficiency, emits of low levels of greenhouse gases and ammonia, and can be reared on biowastes with low water input (FAO, 2013; Makkar et al., 2014; Magalhães et al., 2017). Depending on the rearing conditions, insects also act as good sources of different level of minerals such as potassium, calcium, iron, magnesium, and selenium, and of several vitamins (Henry et al., 2015). Although BSF larvae meal is considered to have a nutritional value close to that of fish meal, using BSF larvae as fish meal alternatives in aquafeeds has not yet been as successful as expected (Henry et al., 2015). Depending of the fish species, maximum dietary fish meal replacement level has ranged from 6 to 50% (Henry et al., 2015; Rana et al., 2015), with highest levels being attained for monosex tilapia, *Oreochromis niloticus* (Rana et al., 2015).

In this regard, Black Soldier Fly can be a prospective solution as larvae consume organic wastes and then upon reaching adulthood may be fed to animals like fish, poultry, swine, reptiles, etc. as a protein supplement. Among the rising techniques, one of the most potential is the culture of BSF larvae as fish feed, a technique that offers the additional benefit of organic wastes utilization (Diener et al., 2009). Managing organic wastes from household or other sources by BSFL and their usage as fish feed in fish farms is a new idea in Bangladesh. Researchers have already successfully introduced BSF larvae by feeding monosex tilapia (Rana et al., 2015). The utility of BSF larvae as an alternative to fishmeal has not been evaluated for common carp, an important commercially farmed fresh water species in Bangladesh. Therefore, it is necessary to address organic aquaculture by applying BSF larvae-based feed in common carp production as well as other fishes at a low-cost input. To reduce the production cost of common carp by progressively replacing fishmeal with BSF larvae and safe guard the environment from pollution we studied the feasibility of BSF larvae based formulated diet for the growth of common carp fry.

2. Materials and methods

2.1 Experimental Diet Composition and Preparation

A feeding trial was conducted at the experimental pond of Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh. In this experiment, five different diets were formulated using BSF larvae where 100 (T_1), 75 (T_2), 50 (T_3) and 25 (T_4) and 0% (T_5) fish meal was replaced with BSF larvae. The BSF larvae were reared at the specialized chamber; separated, washed and dried as previously described by researcher (Rana et al., 2015). Dry feeds were prepared by mixing the ingredients at desired proportions using Pearson's technique (Wagner and Stanton, 2006). Prepared BSF larvae-based diets and dehydrated BSF larvae were sent to the Aquaculture Nutrition Laboratory, FoF, BAU for proximate composition analysis. The proximate compositions (% moisture basis) of the diets are given in Table 1. The prepared feeds were sun dried, then packed in air tight polythene bags and stored in refrigerator at 4°C prior to feeding the fish.

Table 1. Proximate composition of formulated fish feed (% moisture basis)

Name of the treatments	Moisture (%)	Lipid (%)	Crude Protein (%)	Ash (%)	Crude fiber (%)	Carbo-hydrate (%)
T_1 (100% fish meal replaced with BSFL)	13.83	7.08	29.05	8.92	5.20	35.92
T_2 (75% fish meal replaced with BSFL)	15.35	6.66	25.20	11.30	6.40	35.09
T_3 (50% fish meal replaced with BSFL)	13.12	6.09	24.85	11.83	6.80	37.31
T_4 (25% fish meal replaced with BSFL)	11.70	6.40	25.55	13.91	6.66	35.78
T_5 (0% fish meal replaced with BSFL)	13.25	6.30	20.65	15.51	7.20	37.09

*presumed fish meal protein percentage to be 56% but originally found 30%, hence, outcome was less than the required protein level

2.2 Pond preparation and hapa setting

The pond was prepared by removing aquatic weeds manually, and the grasses on the pond dykes were also pruned to very small size. Complete eradication of all undesirable fishes, insects and other aquatic life forms were done by using repeated netting. Then lime was administrated at a rate of 1 kg per decimal. Seven days after liming, the ponds were fertilized with urea, triple super phosphate (TSP) and cow dung at the rate of 100g, 75g and 5kg per decimal respectively. After a week of fertilization, the water was tested for natural food. Then the pond was ready for stocking common carp fry. The fish nursing trial was conducted with two replications in hapas. Ten hapas of 0.76 x 0.61 x 1.07 m3 were prepared with nylon net and were set in two different rows tied with bamboo poles in an experimental pond (Figure 1). The pond water depth was maintained around 1.22 m throughout the experimental period so that the hapas could be submerged 0.91 m under and 0.15 m above the surface of water all the time.

Figure 1. Setting of hapas in the experimental pond.

2.3 Stocking, feeding and sampling of common carp fry

For stocking, common carp (Cyprinus carpio) fry were collected in oxygenated plastic bags from a local hatchery called Satata Hatchery, Digarkanda, Mymensingh. After acclimatization with the pond water, twenty fries were released in each hapa with initial length of 4.61±0.2 cm and weight of 1.59±0.1 g. The fries were fed twice daily at morning and evening. At first the fries were fed with 10% of their body weight for first 4 weeks and then reduced to 8% for next two weeks. After six weeks, the feeding rate was reduced to 5% of their body weight and continued till harvesting. The feeding rate was adjusted in accordance with the standing biomass after each sampling. Sampling of fish was done biweekly. Total length and weight of individual fish were recorded to observe growth response of experimental fish to different feed treatments.

2.4 Growth parameters of fish

Growth and nutritional indices were calculated as followed:

Weight gain (g) = Mean final weight (g) – mean initial weight (g)

$$(\%)\ \text{Weight gain} = \frac{\text{Mean final fish weight} - \text{Mean initial fish weight}}{\text{Mean initial fish weight}} \times 100$$

Length gain (g) = Mean final length (g) – mean initial length (g)

$$(\%)\ \text{Length gain} = \frac{\text{Mean final fish length} - \text{Mean initial fish length}}{\text{Mean initial fish length}} \times 100$$

$$\text{FCR} = \frac{\text{Dry feed fed (g)}}{\text{Live weight gain (g)}}$$

$$\text{FCE} = \frac{\text{Live weight gain (g)}}{\text{Dry feed fed (g)}}$$

Fish production = No. of fish harvested × Mean weight gain

2.5 Data analysis

Collected data were loaded in the computer for statistical analysis. ANOVA was performed with the collected data. Comparison between treatment means was carried out by Duncan's New Multiple Range Test to test the significance of variation between the treatment means. Standard error (SE) of the treatment means was calculated from the residual mean square in the analysis of variance. All statistical analyses were carried out by STAR Nebula (Version 2.0.1) and M-stat-C.

3. Results and Discussion

Growth performance of common carp fry in terms of length (cm) and weight (g) under different treatments for a period of 60 days is graphically presented in Figure 2. In order to evaluate the growth performance of common carp fry the following parameters namely mean length gain (cm), mean weight gain (g), percent length gain, percent weight gain, feed conversion ratio (FCR), feed conversion efficiency (FCE) and production (tons/ha/690 days) were calculated.

Growth performance of common carp fry under different treatments during the study period is presented in Table 2.

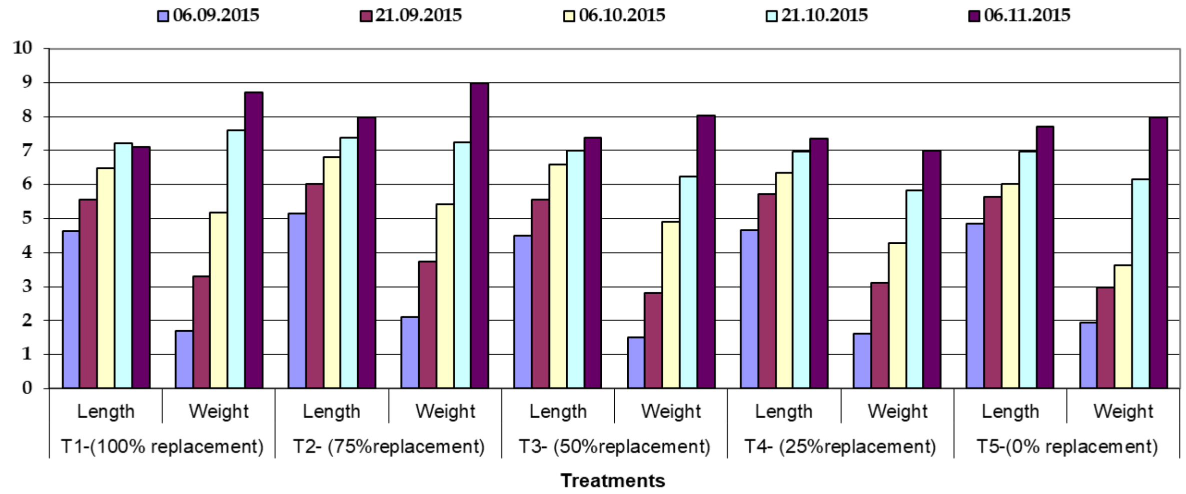

Figure 2. Growth performance of common carp fry in different treatments during the experiment.

Table 2. Growth response and feed utilization of common carp fry fed prepared feed containing graded level of BSF larvae

Treatments	Parameters						
	Length gain (cm)	% length gain	Wt. gain (g)	% wt. gain	FCR	FCE	Production (t/ha/60 days)
T_1 (100% fish meal replaced with BSFL)	2.48	53.39	7.02a	417.70a	3.54	0.285	3.1
T_2 (75% fish meal replaced with BSFL)	2.84	55.4	6.87a	333.49b	3.93	0.256	2.87
T_3 (50% fish meal replaced with BSFL)	2.88	63.95	6.50a	427.95a	3.42	0.297	2.86
T_4 (75% fish meal replaced with BSFL)	2.7	57.96	5.41b	336.59b	4.48	0.223	2.57
T_5 (0% fish meal replaced with BSFL)	2.85	58.9	6.03ab	312.99b	3.98	0.252	2.83
Level of Significance	ns	ns	*	**	ns	ns	ns
CV (%)	10.84	8.83	9.04	9.38	9.69	10.44	8.18

Values in a row having similar letter (s) or without letters do not differ significantly whereas values bearing the dissimilar letter (s) differ significantly as per DMRT. * and ** significant at 5% and 1% level of probability. ns- not significant.

There was no significant difference ($P<0.05$) among the initial length of common carp fry in treatment (T_1), treatment (T_3) and treatment (T_4), whereas the initial length in treatment (T_2) was significantly higher ($P\leq0.05$) than the rest of the treatments (Figure 2). The highest length gain (2.88 cm) and percent length gain (63.95%) of common carp fry was observed in T_3 which was statistically similar with other treatments. Iram *et al.* (2013) recorded the mean length of tilapia 3.87 cm which is slightly higher than the present findings and might be due to the difference in culture period, system and feed used. Dariusz *et al*. (2013) also worked with common carp fry and got more or less similar results which support the present findings. The weight gain and percent weight gain were varied significantly in different treatments. The highest weight gain (7.02 g) was observed in T_1 which was followed by T_2 (6.87 g) and T_3 (6.50 g). In case of percent weight gain, the highest percentage was observed in T_3 (427.95%) which was statistically similar to T_1 (417.70%). Rana *et al*. (2015) found similar result where 50% fishmeal replaced by Dehydrated BSF larvae in the diets of *Oreochromis niloticus* gave the highest weight gain. The highest mean weight gain in T_1 might be due to the more balanced nutrients in the feed than the other treatments.

There was no significant difference in FCR values of different treatments. However, the lowest FCR value (3.42) was observed in T_3 and the highest FCR value (4.48) observed for T_4 (Table 2). FCR value of a feed is an indicator of its quality. It seems that the impact of FCR on the production cost would be more significant during the grow-out stages rather than fry rearing stage as the amount of the consumed feed would be much greater in the grow out phase. All the experimental diets were accepted by common carp fry as there was no left-over feed after half an hour of feeding. Guo *et al*. (2007) observed similar result with a mixture of animal feed ingredients for rearing Cuneate drum (*Nibea miichthoides*). Begum (2009) recorded lower FCR values ranged from 1.03 to 1.20 in tilapia *(Oreochromis niloticus)* culture. In the current study, the lowest FCR value might be due to the efficient food utilization through the extraction of more nutrients from the food and converting it into flesh compared to other diets. Food conversion efficiency was not varied significantly among different treatments showing the highest FCE value (0.297) for T_3 and the lowest FCE value (0.223) for T_4 treatment (Table 2). The production of common carp ranged between 2.57 to 3.10 tons/ha/60 days in different treatments (Table 2). The highest production (3.10 tons/ha/60 days) was obtained in T_1 which was followed by T_2 (2.87 tons/ha/60 days) and T_3 (2.86 tons/ha/60 days) treatments. Treatment T_4 resulted in the lowest production (2.57 tons/ha/60 days). However, no treatment was statistically significant. Newton *et al.* (2005) got similar results and concluded that BSF pre-pupae meal could be advantageous as a replacement of fish meal. Sealey *et al.* (2011) also found that up to 50% of fish meal in trout diets could be replaced with dried ground BSF pre-pupae which also supports the present findings. Common carp fry production varied in the current experiment might be due to fluctuation in dietary protein content (ranged from 20.65 to 29.05%) and ingredients of the prepared diets. This is perhaps due to the balance of essential amino acids from various sources. Although it was intended to maintain 30% protein in the prepared feeds but could not manage due to low quality fishmeal purchased from the local market and maintenance of optimum moisture level.

4. Conclusion

In the present study, better results were obtained by replacing total fish meal suggesting that BSF larvae formulated diet was well utilized for optimal growth of common carp fry. This might be due to the increased palatability, availability of essential amino acids and minerals from diverse sources to support the growth of fish. Comparatively poor digestibility of the chitinous body covering of BSF larvae might be a reason of poor length gain of common carp fry when fed with 100% dehydrated BSF larvae mixture replacing fish meal. This study clearly demonstrated the potential of BSF larvae to supplement fish feed in rural Bangladesh. The potential utilization of BSF larvae meal in future common carp fry diets could reduce farmers and feed manufacturers' dependency on fishmeal as a protein source. This could turn common carp farming into environmentally, socially, and economically sustainable enterprises.

Contribution of Authors

RJ: conceptualization, investigation, methodology, writing original draft, formal analysis, supervision, validation, writing review & editing, MMHT: writing review & editing, resources, software, formal analysis, visualization, MMH: methodology, editing, resources, MAS: conceptualization, investigation, methodology editing & supervision. All authors read and approved the final manuscript.

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