EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 15(2) 2022 152-158
DOI 10.14456/ea.2022.42
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Pleco-based Feedstock for Black Soldier Fly Maggot: Potential Management for Invasive Pleco Fish (*Glyptoperichthys gibbiceps*) in Tempe Lake, Sulawesi Selatan, Indonesia

Khairil Asnan Haedar[1*], Muhammad Ainurridho[2], and Adcharaporn Pagdee[3]

[1] *Biological Science (International Program), Faculty of Science, Khon Kaen University, 40002 Thailand*
[2] *Biology Department, Faculty of Mathematic and Natural Sciences, Universitas Negeri Malang, Indonesia*
[3] *Environmental Science Department, Faculty of Science, Khon Kaen University, 40002 Thailand*

*Corresponding author: khairilasnan.h@kkumail.com
This article received the best oral presentation award in Natural Resource Conservation and Management Session in the 6th EnvironmentAsia Virtual International Conference; December 20-21, 2021 at Bangkok, Thailand,
Revised: January 24, 2022; Accepted: February 28, 2022

Abstract

Pleco fish (*Gliptoperichthys gibbiceps*) is an invasive species at Tempe Lake, Sulawesi Selatan, Indonesia. Increasing population affects native fish and local fishery. The pleco fish obtains no economic value, so discouraging local communities to invest in management projects due to lost costs. A potential of using the pleco fish as feedstock for black soldier fly maggot: BSF (*Hermetia illucens*) was examined. Four treatments (1:1, 1:2, 1:3 and 1:4 w/w of the pleco fish puree: the BSF maggots) were analyzed. The treatment 1:4 obtains the fastest consumption time of average 7.74 hours (SD = 0.20), followed by 1:3, 1:2 and 1:1, respectively. The BSF maggots contain the highest amounts of protein (39.36%), followed by fat (37.00%), and crude fiber (6.86%). The most abundant amino acids are palmitic and palmitoleic acid (24.96% and 21.36%, respectively). These findings determine the potential use of pleco fish for BSF maggot feedstock production. However, further analysis is needed, especially for large scale production.

Keywords: Invasive species; Pleco fish; Black soldier fly maggot; Waste management

1. Introduction

Lake Tempe is one of the biggest lakes in south Sulawesi. The lake provides ecosystem goods and services (e.g., water resources and fishery) that support local livelihoods, especially for Wajo, Sidenreng Rappang (Sidrap), and Soppeng communities. Initial investigations with local villagers living around Lake Tempe revealed a great decline in native fish species such as the Bungo fish (*Glossogobius c.f aureus*), Celebes Rainbow (*Telmatherina ladigesi*) and Binishi (*Oryzias celebensis*). Moreover, increasing population of the pleco fish (*Glyptoperichthys gibbiceps*) was reported, posting threats to native fish species and the lake ecosystem (Dina *et al,* 2019). The pleco fish is listed as an invasive species in Indonesia because of their tolerance to wide environmental conditions. Increasing population of the pleco fish results in decreasing amounts of native fish caught by local fishermen (Salam *et al,* 2020). The pleco fish damaged fishing gears, especially gill nets mostly used by local fishermen (*Amir et al, 2020; Hasrianti et al,* 2020).

Several solutions were proposed by local communities, including direct killing of the pleco fish by sun drying them. It is considered the cheapest approach by local fishermen. A local government also proposed aquaculture feedstock production using the pleco fish, but this cannot be adopted because it is expensive for local communities to do so. Another option is processing the pleco fish to food, but implementation failed due to consumer unfamiliarity and unacceptance. Possible alternatives must answer economic feasibility, social acceptance and ecological sustainability.

Larvae or maggots of the black soldier fly maggot: BSF (*Hermetia illucens*) is a detritivore. Their natural diet is organic materials such as vegetables and fruits even in rotting conditions (Putra and Ariesmana, 2020). BSF maggots contain high amounts of protein with a range of 40 - 50%, carbohydrate content of 0.18% and fat up to 21.17% (Putri *et al,* 2020). Maggot's nutritional contents are mainly influenced by food types. They also affect the maggot's growth rates. BSF maggots rear with feed sources rich in organic matter such as poultry manure can accelerate their growth (Bonelli *et al,* 2020). The pleco fish has potential for the BSF maggot feedstock production. This study examines a possibility of turning the invasive pleco fish into BSF maggot's feedstock, which will offer a potential approach for managing the pleco fish at Lake Tempe. In this study, we focused on examining nutritious contents and consumption rates of the BSF maggots on the pleco fish feed i.e., the time needed for the maggots to finish the pleco-based feed. The study findings will help determine a potential of using the pleco fish for BSF maggot feedstock production. It can be perceived as a win-win solution where the invasive pleco fish can be eradicated, while producing BSF maggots for environmental-friendly waste management. Following this section, we described materials and methods, results, discussion, and conclusions.

2. Materials and Methods

2.1 Materials

Pleco fish samples were obtained from Lake Tempe at the Wajo community location. About 10 kg of the pleco fish were used. They were frozen and minced, while approximately 600 g of one-month old BSF maggots were obtained from the Peduli Nusantara Foundation, Makassar City, South Sulawesi.

2.2 Data collection

Active monitoring was carried out to measure the time that the BSF maggots spent on the given pleco-based feed. Feeding time was measured from the start until all the given feed disappeared (no feed lump was observed, Figure 1). Some parts of the feed given such as fish scale and bone attached the maggots. Monitoring was conducted every thirty minutes to check appearances of the feed lump given. A completely randomized design (CRD) was used in this study with 4 groups of treatments, including 1:1, 1:2, 1:3 and 1:4 w/w of the pleco-based feed over the BSF maggot mass; and 3 replications for each of the treatments (n = 4×3).

Figure 1. Left over feed: fish bones and scales after the BSF maggots finished eating.

2.3 Pre-Experiment

A square container of 20 × 30 × 10 cm was used as a bio-pond for this study. Twelve bio-ponds were arranged linearly and placed at semi-open space (no direct sun light) with good air circulation. Maggots were fasted for 12 hours as a preliminary step to reduce biases in chemical analyses possibly caused by previous feeding from the Peduli Negeri Foundation farmhouse. Subsequently, the maggots were separated into four different bio-ponds.

A total weight of the maggots decreased approximately 12% to 528 g from the initial weight of 600 g. An entire body of the pleco fish were grinded using a meat grinder. The purpose of milling is to puree the fish flesh and to expand a contact area for the maggots when feeding on the pleco fish feed. Feed slurry was pressed to reduce water content and to make the feed in lump forms.

2.4 Experiment

Experiments were carried out by calculating rates of feed consumption (in percentage) with the following ratios of feed per maggots – 1:1, 1:2, 1:3 and 1:4 (w/w). For the calculation to be carried out evenly, the first minute was not counted and was used to mix the maggots with the feed. Feed consumption percentage were calculated by a modified formula from Diener, Zurbrügg, and Tockner, 2009 as the following:

$$Feed\ consumption\ percentage = \frac{Initial\ mass - final\ mass\ of\ the\ feed\ stock}{Initial\ feed\ mass} \times 100$$

The formula determines feed percentage of the maggots to digest the feed at the given time. The initial amount of feedstock used in this study was about 50 g in all the treatments. Final masses of the feedstock were calculated after separating the maggots from the feed residue.

2.5 Chemical Content Analysis

Chemical content analyses were carried out after the feeding completed. The fed BSF maggots were killed using a flame gun and let them dry for 2 days (not directly exposed to sunlight). Afterward, the dried maggots were dried in an oven to make sure they are completely dry as dehydration was required for proximate analyses. About 100 g of dried maggot powder were analyzed to examine nutritious contents and fatty acid types and amounts using Foss (KJELTEC) and GC-MS (Shimadzu QP2010 Ultra). The chemical content analyses were carried out using atomic absorption spectroscopy (Perkinelmer). All the tests were conducted at the Animal Husbandry Integrated Biotechnology Laboratory, Hasanuddin University, Indonesia.

3. Results and discussion

3.1 Consumption time and rates of BSF maggots on the pleco-based feed

Table 1 summarizes feed consumption time, amounts of feed residue, and feed consumption rates. The heavier mass of maggots ate the feed, the shorter time

Figure 2. Bio-ponds (left) and maggots (right)

needed to consume the feed. The fastest consumption rate was observed with the ratio of 1:4, taking 452 minutes or 7.74 hours (SD = 0.20) (Figure 3). The observation lasted until the maggots no longer fed on the feed and no feed lump remain in the bio-ponds. The average feed consumption is 82.5% (SD = 0.06%). The remnants include fish scales and bones; and they were slightly dry.

3.2 Composition of nutrients

Table 2 presents nutrient composition of the BSF maggots taken from sample group 1:4. The proximate analyses reveal high water content indicating that the samples were not completely dry. Two days for sun drying of the samples were insufficient, so longer time is suggested for future analyses. All the tested results were much lower than the AOAC standards.

Table 1. Time of consumption, amounts of residue and consumption rates

Feed to BSF maggots	1:1			1:2			1:3			1:4			$\bar{X}$	SD
Time (Hours)	35.7	35.4	35.5	16.0	16.2	16.0	9.8	9.7	9.1	7.8	7.9	7.5	17.22	11.51
$\bar{X}$ (SD)	35.53 (0.15)			16.08 (0.11)			9.52 (0.34)			7.74 (0.20)				
Residue (g)	11	12	8	8	7	8	12	10	13	4	6	6	8.75	2.83
$\bar{X}$ (SD)	10.33 (2.08)			7.67 (0.58)			11.67 (1.53)			5.33 (1.15)				
Consumption rate (%)	78	76	84	84	86	84	76	80	74	92	88	88	82.50	0.06
$\bar{X}$ (SD)	79.33 (4.16)			84.67 (1.15)			76.67 (3.05)			89.33 (2.30)				

Note: *The final maggot mass calculation is done by filtering the maggot to separate it from the rest of the undigested dry feed. *Initial and final masses are rounded off without decimal places.

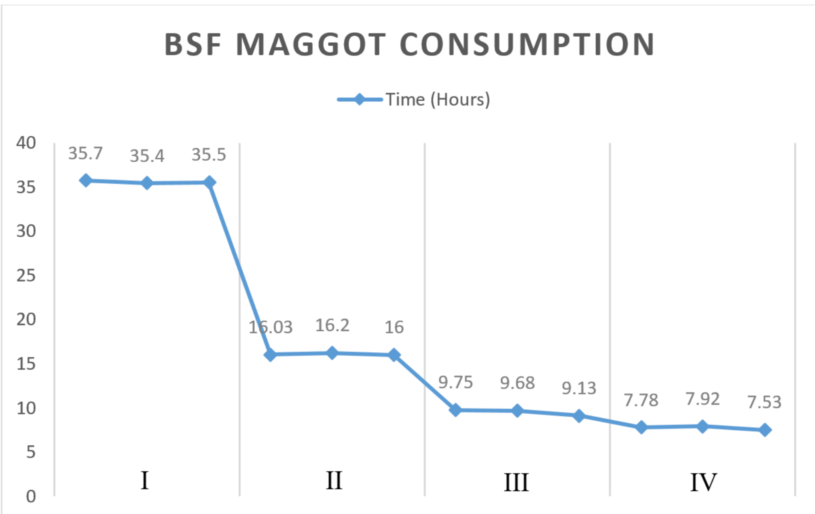

Figure 3. Time of consumption of the BSF maggots on the pleco-based feedstock

Table 2. Proximate analysis result

	Water Content (%)	Ash Content (%)	Protein (%)	Crude Fat (%)	Crude Fiber (%)
Method	**AOAC 930.15**	**AOAC 942.05**	**AOAC 984.13**	**AOAC 920.39**	**AOAC 962.09**
Tested results	50.41	6.49	39.36	37.00	6.86

Note: AOAC = Association of Official Analytical Chemists

3.3 Nutrient analysis

Table 3 summarizes nutrient contents and heavy metal contamination in the BSF maggot samples fed on the pleco-based feedstock. An amount of cadmium is not detected. Meanwhile, average amounts of lead and zinc are higher than tolerance levels according to the Indonesia's National Standard. Pleco fish is a bottom feeder, so amounts of lead and zinc magnified when the pleco fish fed on sludges contaminated with the two heavy metals. Biomagnification occurs through a trophic level in which amounts of contaminated substances increase in higher level consumers like the BSF maggots feeding on the pleco-based feedstock. Heavy metals deposit in exoskeleton (Diener *et al,* 2015). Furthermore, Table 4 presents types and amounts of fatty acids. Amounts of palmitic acid, palmitoleic acid and linoleic acid were high, showing potential of the BSF maggots for poultry feed (Peña-Saldarriaga *et al,* 2020).

3.4 Discussion

The BSF maggots can feed on organic materials, so they show potential to be used for organic waste decomposition. Meanwhile, the pleco fish is perceived as pest for fishermen. One solution offered by a local government in an attempt to kill the fish is soaking them in clove oil. This solution is considered too wasteful because of high price of clove oil. Processing the pleco fish as BSF maggot's feedstock offers an economical and eco-friendly alternative. Increasing demands of BSF-based products, including waste reduction and fishery, can lead to high demands for the pleco fish in near future. This study reveals a potential alternative for invasive species management using natural food chain characteristics.

Nutrient contents, including protein, fiber and fat were high when compared to similar studies using different feeds. For example, Fahmi *et al.* (2007) obtained amounts of protein of 44.26% and fat 29.65%; Bokau & Basuki (2018) fed palm kernel cakes to BSF maggots and got 50.58% of protein yield, 2.76% fat, and 8.10% fiber. Types of food affect protein content. Purnamasari *et al.,* (2019) found that tofu pulps contained high vegetable protein resulting in high protein content of BSF maggots when compared to fruit waste, food waste and cassava peels. The fatty acids identified in this study were dominated by palmitic acid (24.962%), palmitoleic (21.360%), and linoleic acid (9.115%). Palmitic acid is known to increase the ability of lysozyme as an antimicrobial which will make livestock resistant to microbial threats (Lesnierowski and Kijowski, 2007). The addition of linoleic acid to broiler feed is reported to induce broilers to produce more of this acid and can improve meat quality (Cho *et al,* 2013).

Table 3. Chemical and heavy metal contents

	Calcium (Ca)	Phosphorus (P)	Lead (ppm)	Cadmium (ppm)	Zinc (ppm)
Score	3.95	0.61	2.81	nd	1.44
Tolerated score *	-	-	< 0.3 ppm	< 0.1 ppm	< 0.1 ppm

Note: *nd = undetected. *Indonesian standard (SNI) number 7387-year 2009

Table 4. Fatty acid contents

Number	Fatty Acid	Percentage (%)
1	Capric Acid, C10:0	2.705
2	Palmitic Acid, C16:0	24.962
3	Palmitoleic Acid, C16:1	21.360
4	Heptadecanoic Acid, C17:0	1.407
5	Linoleic Acid, C18:2n6c	9.115
6	v-Linoletic Acid, C18:3n6	1.653
Total Fatty Acid		**65.38**

Note: Only above 1% shown

The use of BSF maggots in waste decomposition helps reduce volatile compounds that cause unpleasant odors. No flies around bio-ponds were observed at all during the time of experiment. Moreover, BSF maggots are able to produce compost from their feed. The older the BSF maggots, the better the ability to consume waste, the vulturous they are (Diener, 2010). A recent unpublished project to raise BSF maggots using fruit-based feedstock showed potential by-products, including liquid fertilizer obtained from the drained liquid content from the feedstock, compost from leftovers of the feedstock, dead BSF maggots that can be used as the feedstock for fish, and remaining shells of maggot's pupae are a good source of chitinous substance.

Another advantage of the BSF is that adults (imago) can live independently and do not require food or special maintenance. The imago and larva of the BSF are harmless to human health, and not a vector of any pathogens. In a composting process, BSF larvae can reduce the presence of house flies which usually thrive in organic wastes as well as some pathogenic bacteria, especially *Escherichia coli* and *Salmonella* sp. (Sastro, 2016).

4. Conclusions

The pleco fish is considered as pests at Tempe Lake. In this preliminary study, the pleco fish reveals potential for BSF feedstock production with beneficial by-products such as liquid fertilizer, compost and fish feeds. BSF maggots fed with the pleco fish obtain high amounts of protein and fat content. High content of palmitic and palmitoleic fatty acids are potential to increase the productivity of livestock such as broilers. Turning the pleco fish to BSF feedstock offers a potential alternative for effective and environmental-friendly management of the invasive pleco fish at Tempe Lake. For effective implementation of the pleco-based feedstock production, further studies, especially on local perception towards this project and cost-benefit analysis are needed.

Acknowledgements

This study was supported by Mr. Wahyu as the key informant at Tempe Lake, also with the help from the Wajo government to mediate us with community members, especially fisherman.

References

Amir N, Syahrul, Djamaluddin N. Ikan Sapu-Sapu (Pterygoplichthys pardalis) Di Kabupaten Wajo Propinsi Sulawesi Selatan: Kandungan Logam Berat Timbal (Pb), Merkuri (Hg) dan Arsen (As) (Suckermouth Catfish (Pterygoplichthys pardalis) In Wajo Regency, South Sulawesi Province: The Heavy Met. Agrikan [Internet]. 2020; 13(2): 173–4. Available from: https://ejournal.stipwunaraha.ac.id/index.php/AGRIKAN/article/download/398/pdf

Bokau RJM, Basuki P. Bungkil Inti Sawit sebagai Media Biokonversi Produksi Massal Larva Maggot dan Uji Respon Pemberian pada Ikan Nila (Oreochromis niloticus). Pros Semin Nas Pengemb Teknol Pertan VII. 2018;122–8.

Bonelli M, Bruno D, Brilli M, Gianfranceschi N, Tian L, Tettamanti G, et al. Black Soldier Fly Larvae Adapt to Di ff erent Food Substrates through Morphological and Functional Responses of the Midgut. Int J Mol Sci. 2020; 21(14):1–27.

Cho S, Ryu C, Yang J, Mbiriri DT, Choi C-W, Chae J-I, et al. Effect of Conjugated Linoleic Acid Feeding on the Growth Performance and Meat Fatty Acid Profiles in Broiler: Meta-analysis. Asian-Australasian Journal Animal Science [Internet]. 2013 Jul; 26(7): 995–1002. Available from: https://pubmed.ncbi.nlm.nih.gov/25049878

Diener S, Zurbrügg C, Tockner K. Conversion of organic material by black soldier fly larvae: establishing optimal feeding rates. Waste Management and Research [Internet]. 2009; 27(6): 603–10. Available from: https://doi.org/10.1177/0734242X09103838

Diener S. Valorisation of organic solid waste using the black soldier fly, Hermetia illucens L., in low and middle-income countries. ETH Zürich; 2010.

Diener S, Zurbrügg C, Tockner K. Bioaccumulation of heavy metals in the black soldier fly, Hermetia illucens and effects on its life cycle. Journal Insects as Food Feed. 2015; 1(4): 261–70.

Dina R, Lukman, Wahyudewantoro G. Status jenis iktiofauna Danau Tempe , Sulawesi Selatan Ichthyofauna state of Lake Tempe, South Sulawesi. 2019; 5(2014): 251–5.

Fahmi MR, Hem S, Subamia IW. Potensi maggot sebagai salah satu sumber protein pakan ikan. Dukungan Teknol Untuk Meningkat Prod Pangan Hewan Dalam Rangka Pemenuhan Gizi Masyarakat Pros Semin Nas Hari Pangan Sedunia XXVII. 2007; 125–30.

Hasrianti, Surianti, Putri RS, Damis, Rahmat MR, Arif SH. Analisis Pengaruh Ledakan Populasi Ikan Sapu-Sapu (Pterygoplichthys Spp) Terhadap Pendapatan Nelayan Jaring Insang di Perairan Danau Sidenreng. 2020; 16(3): 382–8.

Lesnierowski G, Kijowski J. Bioactive Egg Content. Huopalahti R, López-Fandiño R, Anton M, Schade R, editors. Springer International Publishing; 2007.

Peña-Saldarriaga LM, Fernández-López J, Pérez-Alvarez JA. Quality of Chicken Fat by-Products: Lipid Profile and Colour Properties. Foods (Basel, Switzerland). 2020 Aug; 9(8).

Purnamasari L, Sucipto I, Muhlison W, Pratiwi N. Komposisi Nutrien Larva Black Soldier Fly (Hermetia illucent) Dengan Media Tumbuh, Suhu dan Waktu Pengeringan yang Berbeda. 2019; 675–80.

Putra Y, Ariesmana A. Efektifitas Penguraian Sampah Organik Menggunakan Maggot (BSF) di Pasar Rau Trade Center. JURNALIS. 2020; 3(1): 11–24.

Putri MC, Delima EM, Asnilawati. Uji Kandungan Protein, Karbohidrat dan Lemak pada Larva Maggot (Hermetia illucens) yang Diproduksi di Kalidoni Kota Palembang dan Sumbangsihnya Pada Materi Insecta di Kelas X SMA/MA [Internet]. UIN Raden Fatah Palembang; 2020. Available from: http://repository.radenfatah.ac.id/id/eprint/8183

Salam S, Tantu AG, Pallawagau M. Penyelesaian Masalah Sosial Ekonomi Masyarakat Kawasan Danau Tempe , Sulawesi Selatan. 2020; 7(1): 24–40.

Sastro Y. Teknologi Pengomposan Limbah Organik Kota Menggunakan Black Soldier Fly. Jakarta Selatan: BPTP Jakarta; 2016.