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Original Article

Utilization of Black Soldier Fly Larvae in Restaurant Waste Management in Tanjung Ayun Sakti Village

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ABSTRACT

Background: The management of organic waste from restaurants in urban areas remains a significant environmental challenge because it contributes to pollution and increased greenhouse gas emissions. Bioconversion using Black Soldier Fly (BSF) larvae offers a promising solution for the rapid decomposition of organic waste while producing biomass products that have economic value. This study aims to evaluate the performance of BSF larvae with different initial weights (10 g, 20 g, and 30 g) in processing organic waste from restaurants.
Methods: This experimental study with an observational approach used organic waste collected from restaurants in Tanjung Ayun Sakti Village. Five-day-old BSF larvae, which were cultivated under controlled conditions, were used in three treatment groups based on the initial weight of the larvae (10 g, 20 g, and 30 g). Larval performance was measured through waste reduction index, bioconversion rate, and feed conversion ratio.
Results: The results showed that the waste reduction index for the use of 10 g, 20 g, and 30 g of larvae was 40.37%, 55.15%, and 59.27%, respectively. The bioconversion rate for the use of 10 g, 20 g, and 30 g of larvae is 2.96%, 6.67%, and 7.78%, respectively. The feed conversion rate when using 10 g, 20 g, and 30 g of larvae, respectively, was 33.75, 15.00, and 12.86. larvae biomass increased significantly with final yields of 267 g, 600 g, and 700 g.
Conclusion: The results showed that the use of 30 g of larvae was the most effective compared to 10 g and 20 g of larvae based on the data waste reduction index, bioconversion rate, and feed conversion ratio. Overall, the significant increase in final larval biomass, reaching up to 700 g, confirms that higher larval quantities have a markedly positive impact on bioconversion efficiency and biomass productivity.

INTRODUCTION

Food is an essential human need required for daily activities. However, despite its important role in sustaining life, the production and consumption of food generates a significant amount of waste, especially food waste. Organic waste has become a major problem worldwide over the last decade, especially in developing countries. Organic waste is one of the most commonly produced types of waste, yet it is often poorly managed. Food waste is becoming an increasingly urgent environmental problem, especially in urban areas, where food consumption is high, and waste management is often irregular (Handoyo & Asri, 2023; Tondo et al., 2024). According to the Food and Agriculture Organization (FAO), approximately 931 million tons of food is wasted worldwide, with households contributing approximately 570 million tons, or 60% of the total food waste (Hartono et al., 2021). In 2017, the Economist Intelligence Unit (EIU) reported that Indonesia had the second-highest food waste production in the world, after Saudi Arabia, with 46.35 million tons per year. On average, Indonesians throw away approximately 28 kg of food every year. This waste is dominated by vegetables (25.89%), fruits (17.73%), and soy-based products such as tofu (9.93%) (Wahyudi et al., 2024).

Specific data on food waste in the Riau Islands Province is currently unavailable. However, based on data provided by the Riau Islands Province Environment Agency, the percentage of food waste is 35.06% (Kementerian Lingkungan Hidup dan Kehutanan 2023). Most food waste comes from hotels, restaurants, eateries, catering services, supermarkets, retail stores, and households. This waste includes food that has expired but has not been consumed or removed from its packaging. Organic waste from eateries includes vegetables, fruits, and other unused food items that need to be discarded, in addition to food leftovers that have not been consumed by customers (Florida, 2022; Hermanu, 2023). Restaurants dispose of organic waste without implementing adequate sorting and processing procedures, making them one of the main contributors to organic waste generation. Food waste from customer leftovers and unused raw materials is are example of organic waste that restaurants often dispose of (Syafaat and Syafaat, 2023).

Improperly managed waste decomposes and produces methane gas (CH_4), which contributes to global warming, and hydrogen sulfide gas (H_2S), which has an unpleasant odor and is harmful to human health (Hasanah et al., 2022; Sofianto et al., 2024). Most restaurants in Tanjung Ayun Sakti Village do not have a proper organic waste management system. Although some restaurant owners sell their organic waste, most dispose of it directly into landfills without processing. If this situation continues, the Environmental Agency will have to handle increasing amounts of waste, and the level of environmental pollution in the area will increase (Tara, 2023).

Utilizing BSF larvae as bioconversion agents is one way to address the problem of organic waste (Agustiyani et al., 2021; Ichwan et al., 2021). BSF larvae can naturally break down organic waste with a high level of efficiency, enabling a reduction in waste volume of up to 80%. BSF larvae can help reduce waste volume in landfills by reducing the mass of organic waste by up to 56. In addition, the grown larvae can be used as livestock feed that is rich in protein, and the remains of the decomposition can be used as organic fertilizer (Nofiyanti et al., 2021; Rukmini et al., 2020; Silalahi et al., 2022). The method of processing organic waste using BSF larvae has many advantages, including a high level of efficiency in reducing organic waste, because BSF larvae can consume large amounts of various types of organic waste. In addition, BSF larvae can convert organic waste into biomass and produce products of economic value, such as BSF larvae that can be used as feed for livestock, fish, poultry, and other sources of nutrition (Kinasih et al., 2020; Mutiar & Yulhendri, 2020). In addition, this method reduces greenhouse gas emissions by preventing the formation of methane from the decomposition of organic waste. Furthermore, BSF larvae can accelerate the decomposition of organic waste (Fadhillah & Bagastyo, 2020; Khairuddin et al., 2022; Oktavia & Rosariawari, 2020).

Although the use of Black Soldier Fly (BSF) larvae for organic waste management has been widely recognized, studies specifically investigating how variations in larval density or initial larval weight affect the processing of restaurant-derived organic waste in urban environments are lacking. Many prior investigations have relied on uniform, controlled substrates or have not compared different starting larval weights under standardized conditions. Furthermore, comprehensive data on key larval performance indicators, such as waste reduction index, bioconversion rate, and feed conversion ratio, across different larval quantities using actual restaurant waste remains limited. This shortage of evidence leaves an important gap in understanding how larval density influences processing efficiency and biomass productivity in real-world urban waste-management systems. This study makes several important contributions by presenting a comparative assessment of Black Soldier performance across three starting larval masses (10, 20, and 30 g) using real restaurant organic waste from an urban setting. It provides comprehensive quantitative data, including the waste reduction index, bioconversion rate, and feed conversion ratio generated under actual waste conditions, offering essential insights for improving BSF-based waste treatment systems. Overall, this study provides practical value for urban waste management by demonstrating that adjusting larval density can enhance organic waste reduction while simultaneously yielding biomass with economic potential.

Most restaurants in Tanjung Ayun Sakti Village dispose of their organic waste without first undergoing treatment. Therefore, this study aimed to evaluate the performance of BSF with different initial weights (10, 20, and 30 g) in treating restaurant organic waste.

METHODS

This study employed an experimental approach with observational components to assess the performance of *Black Soldier Fly* (BSF) larvae in processing restaurant-derived organic waste. The experiment was conducted from April to August 2025 using organic waste collected from a local food establishment in Tanjung Ayun Sakti Village. A Completely Randomized Design (CRD) was implemented with three levels of larval biomass—10 g, 20 g, and 30 g—each replicated three times, resulting in a total of nine experimental units. The larvae used in this study were five days old and sourced from the BSF breeding facility at the Health Polytechnic of the Ministry of Health, Tanjungpinang. A total of 9 kg of organic waste was prepared and evenly distributed across all units. Controlled variables included the amount of waste provided, larval age, as well as uniform mixing procedures and feeding schedules across treatments. Environmental parameters such as temperature and humidity were not monitored; therefore, environmental conditions were assumed to remain relatively constant throughout the study and were not included in the analysis.

Data collection involved direct observation of the bioconversion process carried out by BSF larvae. The measured parameters included the waste reduction index, bioconversion rate, and feed conversion ratio.

The Waste Reduction Index (WRI) was calculated using the formula:

$$\mathrm{WRI} = \frac{W_{\mathrm{initial}} - W_{\mathrm{final}}}{W_{\mathrm{initial}}} \times 100$$

The Bioconversion Rate was determined using:

$$\text{Bioconversion Rate} = \frac{W_{\text{final larval biomass}}}{W_{\text{initial waste}}} \times 100$$

Meanwhile, the Feed Conversion Ratio (FCR) was computed as:

$$\mathrm{FCR} = \frac{\text{Total waste consumed}}{\text{Final larval biomass}}$$

Various tools, including an analytical balance, plastic buckets, basins, knives, gloves, masks, and writing materials, were used during the study. The materials included 3 g of BSF eggs, 9 kg of restaurant organic waste, and 1.5 kg of coconut pulp as the initial larval medium.

Data were analyzed descriptively (univariate analysis) to illustrate the bioconversion performance of the BSF larvae. Results are presented in the form of mean values, percentages, tables, graphs, and narrative descriptions. No inferential statistical tests were applied; thus, the findings reflect general patterns and tendencies in the bioconversion process across treatments rather than statistical comparisons.

RESULTS

Based on the results of the study, it is known that variations in the number of BSF larvae have an effect on the reduction in the weight of organic waste from restaurants.

Table 1. Waste Reduction Index (WRI)

5 day old BSF larvae (g)	Time (Day)	Waste Reduction Index (%)				SD
		P1	P2	P3	Mean	
10	12	28.9	37.8	54.4	40.37	12.92
20	12	41.1	55.6	68,9	55.15	13.93
30	12	46.7	61.1	70	59.27	11.71

Source: Primary Data, 2025

Table 1 shows that the highest waste reduction index value was obtained from the treatment using 30 g of larvae, which was 59.27%, while the waste reduction index values using 20 g and 10 g of larvae were 55.15% and 40.37%, respectively.

Table 2. Bioconversion Rate

5 day old BSF larvae (g)	Initial waste weight added (g)	Bioconversion Rate (%)				SD
		P1	P2	P3	Mean	
10	9.000	2.22	2.22	4.44	2.96	1.28
20	9.000	5.56	3.33	11.11	6.67	4.01
30	9.000	7.78	3.33	12.22	7.78	4.45

Source: Primary Data, 2025

Table 2 shows that the highest bioconversion rate measurement value was in the treatment using 30 g of larvae, which was 7.78%, while the bioconversion rate measurement values using 20 g and 10 g of larvae were 6.67% and 2.96%, respectively.

Table 3. Feed Conversion Ratio (FCR)

5 day old BSF larvae (g)	Berat sampah awal ditambahkan (g)	Feed Conversion Ratio				SD
		P1	P2	P3	Mean	
10	9.000	45	45	23	33.75	12.70
20	9.000	18	30	9	15.00	10.54
30	9.000	13	30	8	12.86	11.53

Source: Primary Data, 2025

Table 3 shows that the lowest feed conversion ratio measurement value was in the treatment using 30 g larvae, which was 12.86, while the feed conversion ratio measurement values using 20 g and 10 g larvae were 15.00 and 33.75, respectively.

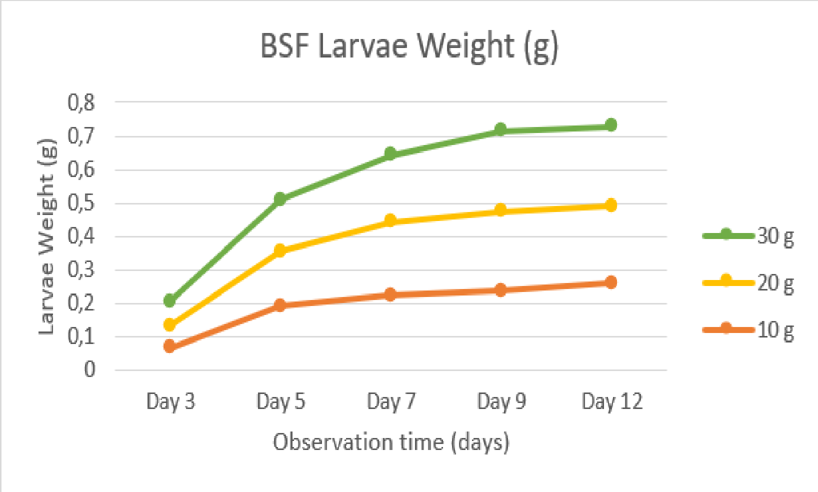

Figure 1. Larvae Biomass Weight

Figure 1 shows the development of BSF larvae biomass weight in three variations of larvae numbers, namely 10 g, 20 g, and 30 g, during 12 days of observation, showing a consistent and significant growth pattern. The variation with 30 g of larvae consistently produced the highest larval biomass weight compared to the 20 g and 10 g variations. From day 3 to day 12, the larval weight graph for the 30 g treatment was always higher than the other two treatments, indicating that the more larvae used, the greater the biomass produced in the same period of time.

DISCUSSION

This study examines the effectiveness of using Black Soldier Fly (BSF) larvae in processing organic waste from restaurants with varying numbers of larvae. Waste reduction index, bioconversion rate, and feed conversion ratio are important parameters used to measure the effect of changes in the number of larvae on the waste bioconversion process. To maximize the use of BSF larvae as an economical and environmentally friendly waste decomposing agent, it is important to understand the effect of variations in the number of larvae. The following section will discuss the effect of variations in the number of larvae on each of these parameters.

Waste Reduction Index

The effectiveness of Black Soldier Fly larvae in decomposing organic waste during the bioconversion process was assessed using an important parameter, namely the Waste Reduction Index. This parameter calculates the percentage of waste reduction achieved each day, where a higher waste reduction index value indicates that the larvae are more capable of reducing waste, thereby reducing the amount of residue. The results of the study show that variations in the number of BSF larvae have an effect on the waste reduction index. Specifically, in the treatment with 30 g of larvae, the waste reduction index value was recorded at 59.27%, higher than the treatments with 20 g and 10 g of larvae. These results indicate that a larger number of larvae contributes significantly to the success rate of decomposing organic waste from restaurants. The higher the waste reduction index percentage, the less waste residue is discarded (Dewi et al., 2021). During the decomposition of organic waste, it has been shown that the number of larvae helps increase metabolic activity (Kofsoh et al., 2023).

Bioconversion Rate

In addition, this study examined how changes in the number of larvae affected the bioconversion rate, a ratio that indicates the ability of larvae to convert organic waste substrates into biomass. The bioconversion rate is an important indicator for measuring how efficiently larvae utilize available substrates. The results of the study show that the treatment with 30 g of larvae produced the highest bioconversion rate of 7.78%, followed by the treatments with 20 g and 10 g. This study shows that a larger number of larvae contributes to increased biomass production. These results are in line with previous studies (Rohmanna et al., 2023) which states that an increase in the number of larvae significantly affects the bioconversion rate, with values ranging from 4.50% to 14.40%. This range indicates that BSF larvae have a significant ability to convert organic waste into useful biomass.

In addition, the bioconversion rate is one of the main parameters used to measure the ability of BSF larvae to reduce substrates and convert them into biomass. The higher the bioconversion rate, the greater the efficiency of BSF larvae in converting substrates into biomass (Kofsoh et al., 2023). Thus, the increased bioconversion rate at higher larval numbers indicates that larval numbers play an important role in determining the effectiveness of the organic waste bioconversion process.

Increasing the density of *Hermetia illucens* larvae has been shown to accelerate the bioconversion of organic waste through complex biological interactions. A higher number of larvae enhances total substrate consumption, while their aggregation behavior generates thermogenesis — a local temperature increase of several degrees — which stimulates metabolic activity and accelerates substrate degradation (Klammsteiner et al., 2025). Furthermore, larval density alters the composition of the gut microbiota; metagenomic analyses reveal that certain metabolically functional microbes, such as bacteria encoding cobalamin synthesis genes, correlate positively with larval growth (Ijdema et al., 2025). The synergistic effects of increased consumption, optimized thermal conditions, and microbial activity explain why higher larval numbers result in more efficient waste conversion and greater biomass production.

Overall, identifying an optimal larval density is essential to balancing heat generation, nutrient access, and enzymatic activity. The selection of appropriate density levels allows the bioconversion process to proceed efficiently without inducing thermal stress or nutrient limitation. Previous studies highlight the importance of tailoring larval density to substrate characteristics, nutrient composition, and microclimatic conditions to maximize biomass conversion and maintain system stability (Lalander et al., 2019).

Feed Conversion Ratio

Furthermore, this study also examined the effect of larval number variation on feed conversion ratio. Feed conversion ratio itself is the ratio between the amount of feed consumed and the larval biomass produced. A low feed conversion ratio indicates high feed efficiency, as larvae are able to produce greater biomass with less feed consumption. The results of the analysis show that the treatment with 30 g of larvae produced the lowest feed conversion ratio of 12.86, followed by the 20 g and 10 g treatments.

The low feed conversion ratio in the treatment with 30 g indicates that this amount of larvae is most effective in converting organic waste into biomass. This study is in line with the theory that states that the higher the bioconversion rate, the lower the feed conversion ratio tends to be, reflecting better feed conversion efficiency (Rohmanna et al., 2023). Therefore, optimal larval population control not only accelerates the waste decomposition process, but also improves feed efficiency. This indicates that a low feed conversion ratio signifies a higher level of feed conversion efficiency (Kofsoh et al., 2023).

In general, the results of this study indicate that variations in the number of larvae play an important role in the process of treating restaurant organic waste using BSF larvae. An increase in the number of larvae has been shown to contribute significantly to the waste reduction index, bioconversion rate, and feed conversion efficiency. Thus, regulating the number of larvae can be an effective strategy for optimizing the biological treatment of organic waste.

Determining the effective number of larvae is very important in the application of bioconversion technology, because the ideal number of larvae will increase the efficiency of organic waste decomposition, produce larval biomass with high protein content, and minimize the amount of residue remaining. The effectiveness of the bioconversion process is not only marked by a reduction in waste volume, but also by the quality of the conversion results in the form of economically valuable BSF larvae and minimal residue. Thus, managing the right number of larvae is key to creating a sustainable and efficient organic waste treatment system.

Study Limitations

The limitations of this study are that it is difficult to control variations in the types of restaurant waste, such as oil, salt, or spices, which have the potential to inhibit the growth of BSF larvae. The presence of other types of flies that interfere with and may compete with BSF larvae or contaminate the research media. The experimental design tested only three initial larval densities without accounting for environmental factors such as temperature and humidity that may influence conversion efficiency.

CONCLUSION

This study shows that the use of Black Soldier Fly larvae is effective in reducing organic waste from restaurants. The 30 g larvae variant produced the highest waste reduction index (59.27%), the best bioconversion rate (7.78%), the most efficient feed conversion ratio (12.86), and the highest larval biomass with the least waste residue. These results confirm that an increase in the number of larvae is directly proportional to the effectiveness of organic waste decomposition. Efforts to determine the optimal number of larvae to convert 9 kg of organic waste to the maximum extent possible need to be undertaken. Further experiments with higher larval densities are recommended to identify optimal biomass conversion efficiency under varying restaurant waste compositions. incorporate more diverse waste sources, longer experimental durations, and additional biological and environmental measurements to strengthen the understanding of BSF-driven waste processing.

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