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Reduction of Organic Waste Using Black Soldier Fly *Hermetia illucens* Larvae (BSF) Technology

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Abstract

The waste problem is a significant issue faced by developing countries like Indonesia. It is caused by the increasing population and economic growth, leading to a rise in waste generation. The objective of this studi was to examine the efficiency of feed types on the development of BSF larvae in decomposing organic waste and to study the final reduction in organic waste levels after being decomposed by BSF larvae. Three types of processing media reactors were used for a duration of 14 days, with each reactor being treated differently. The M1 reactor the composition of the type of waste given to BSF larvae in the M1 reactor is organic waste, especially rice waste and vegetable waste with a total amount of 5 kg, then 5 kg of tofu waste is added as a change and comparison to the composition of the feed in the M1 reactor. The M2 reactor is organic waste, especially rice and vegetable waste, with a total amount of 10 kg. The M3 reactor is tofu dregs waste with a total amount of 10 kg. This research showed that the conversion efficiency value of feed digested by BSF larvae, in M1 which gets an ECD value of 10.47%, then reactor M2 gets an ECD value of 5.65%, while in the M3 reactor the highest ECD value was obtained with a value of 11.67%. The final water content of organic waste is a range of 53.43-58.49%. The final pH value in the range of 5.90-7.10. The C/N ratio final in a range of 11.92-15.74.

Keywords: *Biodegradable, black soldier fly, organic waste, tofu dreg*

INTRODUCTION

The waste problem is a common problem faced by several developing countries, including Indonesia. The biggest factor contributing to the increase in waste generation is the increase in population which is accompanied by economic growth activities from population activities so that the amount of waste income increases (Widyastuti & Sardin, 2021). One of them is the city of Surabaya which has a very large population, namely around 2.9 million people in 2020 (Pintowantoro *et al*., 2022). This large population also influences waste production in Surabaya. In the context of processing organic waste, alternative technology is needed that is suitable and adequate in this case,

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such as waste composting methods. The compostor method is a technique for producing compost from organic materials through a decomposition process with the help of decomposing microorganisms (Dewi *et al*., 2020). So, the processing offered uses BSF larvae as a bioconversion agent for organic waste. BSF larvae are very suitable for use as a reducer for large volumes of organic waste while also reducing the pungent odor from decomposing waste (Oktavia & Rosariawari, 2020). The results obtained from related research, (Diener *et al*., 2011) state that the waste reduction value is around 40% as achieved in the laboratory, household waste can be reduced from 65% to 75%. (Salman *et al*., 2020) stated that the results of the analysis that had been carried out showed that the waste reduction speed was 74.6% for samples without grinding and 87.1% for samples that were ground. Dafri *et al*., 2022 based on the research results, the reduction percentages obtained were 42.29, 42.92%, 33.75%, and 46.25%.

BSF larvae's protein and fat composition of BSF larvae is influenced by what they consume. The effect is not always linear: experiments using food waste mixtures with known protein/fat composition found that using more protein resulted in more proteinaceous BSF larvae, but the percentage of fat in the substrate did not correlate with the rate of larval fat (Wang & Shelomi, 2017). Tofu dregs can be used as a protein source feed ingredient because they contain high crude protein levels. BSF *Hermetia illucens* is a true fly (Diptera) from the Stratiomyidae family. Although originally native to the Americas, it now occurs worldwide in tropical and temperate regions, and its lack of cold resistance precludes invasion into non-native areas such as Northern Europe. BSF flies are not dangerous to human safety and health. These flies are usually found outdoors (house flies are indoors) and are often found in areas or places that contain organic material, especially livestock pens and collections of dead organic waste (Mahmud *et al*., 2020). (Sastro, 2016) stated that BSF larvae can consume organic material, so they can be used to reduce and decompose cage waste for several types of ruminants and poultry. In this research, BSF larvae are used as organic waste bioconvertion which will be combined with tofu dregs waste. Measurements are carried out using (Waste Reduction Index) WRI and (Efficiency of Conversion Digested feed) ECD parameters to find out how effective and efficient the various types of waste provided are. The objective of this studi was to examine the efficiency of feed types on the development of BSF larvae in decomposing organic waste and to study the final reduction in organic waste levels after being decomposed by BSF larvae.

METHODS

Research Location

The research was conducted in the yard of the Universitas PGRI Adi Buana Surabaya, Dukuh Menanggal XII/4 Surabaya, 60234, Indonesia.

Sample Determination

The research will be carried out with 1 (one) variable, namely differences/modifications in the type of organic waste that will be provided. The different types of feed that will be used are organic waste, especially rice and cucumber waste resulting from household activities, and a mixture of tofu dreg waste with different compositions. Feeding of BSF larvae is regulated as follows:

1. Reactor (M1)
   The composition of the type of waste given to BSF larvae in the M1 reactor is organic waste, especially rice waste and vegetable waste with a total amount of 5 kg, then 5 kg of tofu waste is added as a change and comparison to the composition of the feed in the M1 reactor.
2. Reactor (M2)
   The feed for the M2 reactor is organic waste, especially rice and vegetable waste, with a total amount of 10 kg.
3. Reactor (M3)
   The feed for the M3 reactor is tofu dregs waste with a total amount of 10 kg.

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Parameter Measurement

In this research method, a study was carried out on the effectiveness of waste degradation by BSF larvae. The basic aim of this research is to use BSF larvae to decompose organic waste, which is carried out in a trial study using different types of organic waste provided. The study carried out initial measurements before the organic waste was given and measurements of the final material resulting from the excretion process by BSF larvae. Measurements include water content, pH, and C/N ratio, and the effectiveness of the reduction speed is measured through WRI and ECD calculations. Preparations for breeding the number of larvae that will be used for this experiment are calculated from the weight per gram of BSF eggs, 10 g per reactor; then culture is carried out for 6 days in 3 (three) media bottles of 10 grams each before the BSF larvae are used in the main processing medium. After the breeding stage, the BSF larvae are 7 days old and ready to be used in the research process, which will be carried out over a 14-day running period

Reactor Design

This research used 3 (three) reactor media M1, M2 and M3 which at the time of the study consisted of 3 (three) types of treatment in each reactor. The reactor design uses a media container with a volume of 20 liters, 36 cm wide, 45 cm long, and 15 cm high. Then, the media is put into a net with a width of 50 cm, a length of 50 cm, and a height of 100 cm. The reactor design can be seen in Figure 1

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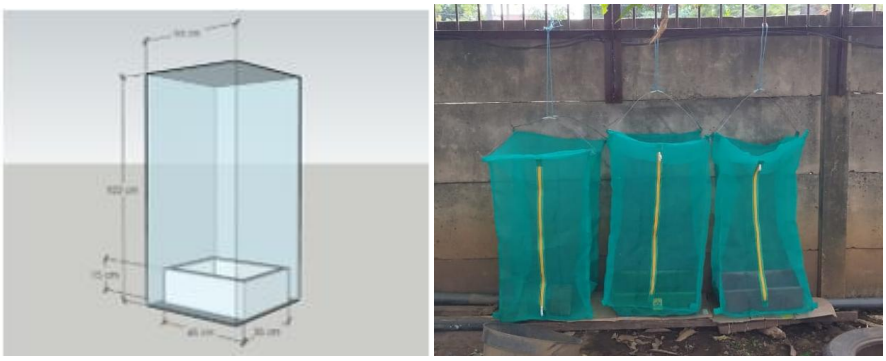

(a) (b)

Figure 1. Reactor design and research reactor prototype. (a) Schematic diagram of the reactor design, illustrating key components and process flow. (b) The research reactor used in this study was developed based on the design shown in (a).

Research Phase

The initial research stage requires 1-2 days for egg hatching and breeding until the larvae begin to consume waste until on the 6th day actively. Then, the research started on the 7th day with a running time of 14 days per reactor. For 14 days, the larvae will be given food using a continuous system for two treatments, feeding is carried out in the first week and the second week according to the portion provided and stopped on the 15th day.

Calculation of WRI and ECD Values

Determining the level of waste reduction by BSF larvae is influenced by 2 (two) factors: the level of waste degradation and the time required to degrade the waste. Measuring the speed of waste reduction by BSF larvae is determined by the quantity of trash that will be provided. (Diener, 2010) defines the level of waste reduction by BSF larvae as WRI with the following equation:

$$WRI = \frac{D}{t} \times 100 \quad \text{.....(1)}$$

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$$D = \frac{W - R}{W}$$ .....(2)

Where:

WRI is the waste reduction index (%), D is the level of waste gradation, T is the time needed to degrade the waste (Days), W is the amount of waste before it is degraded (g), and R is the amount of residue (g).

The ECD value describes the amount of food eaten by BSF larvae and shows the efficiency of BSF maggots in converting the food eaten into biomass. The higher the ECD value, the higher the level of efficiency.(Diener, 2010), defines the level of waste reduction by BSF larvae as ECD with the following equation:

ECD = $\frac{B}{I-F}$ x 100%.....(3)

Where:

ECD is the efficiency of conversion of digested feed, B is the increase in maggot weight during the feeding period, obtained from subtracting the final weight of the maggot from the initial weight of the maggot, I is the amount of feed consumed; obtained from subtracting the initial weight of the feed from the final weight of the feed (mg) the initial weight of the maggot (mg), F is the weight of the remaining feed and excreted material (mg).

RESULTS AND DISCUSSION

The results of the analysis of waste reduction index values by BSF larvae in each reactor carried out during research with a running period of 14 days showed that differences in the type of feed provided could influence the level of organic waste degradation by BSF larvae. The results of the research discussion indicate a low waste reduction index value, including a study of the speed of waste reduction by BSF larvae from different types of feed in each reactor through WRI and ECD measurement tests. Characteristics testing of organic waste was also carried out by measuring the parameters of water content, pH, and the initial and final C/N ratio after the research in order to determine changes in the characteristics contained in the initial waste before processing and after processing, which were taken from the excreted material by BSF larvae.

WRI Value

Determining the level of waste reduction by BSF larvae is influenced by 2 (two) factors: the level of waste degradation and the time required to degrade the waste. Measuring the speed of waste reduction by BSF larvae is determined by the quantity of waste that will be given; this study using different types of waste with an amount of 14 kg each that will be given to the larvae from each reactor. The M1 reactor consists of 50% tofu dregs waste, 25% rice waste, and 25% cucumber waste, then the M2 reactor consists of 50% rice waste and 50% cucumber waste. In comparison, the M3 reactor consists of 100% tofu dregs waste, all types. The total amount of waste is 10 kg per reactor and is added twice in the first and second weeks with an additional amount of 2 kg per reactor, as a weekly control. Data values for the initial amount of waste and the resulting weight of excreted material are shown in Table 1.

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Table 1. Waste Reduction Index Value

Reactor	Amount of Waste (g)	Reduction (g)	Residue (g)	WRI%	Degradation Time (Days)
M1	14,000	13,255	745	6.75	14
M2	14,000	12,775	1,225	6.51	14
M3	14,000	13,639	370	6.95	14

The fact is that there is still a lot of food residue during treatment because the larvae consume little food and leave behind a lot of larval food and feces. A comparison of the reduction index values for each reactor can be seen in Table 1. The WRI value in reactor M1 is 6.75% with the treatment of 50% tofu dregs waste, 25% rice waste, and 25% cucumber waste. While reactor M2 has a value of 6.51% with treatment of 50% rice waste and 50% cucumber waste, then the M3 reactor was 6.95% with 100% treatment of tofu dregs waste. The results of the data on the level of waste degradation by BSF larvae showed that the highest value was obtained from the M3 reactor of 6.95% with 100% treatment of tofu dregs waste. The high WRI value in the M3 reactor is influenced by the type of feed provided in the form of 100% tofu dregs waste which has relatively high protein and fat content. According to (Balhis *et al*., 2022) the nutritional content of protein and fat is the preferred food for larvae, thereby increasing waste consumption. Larvae utilize feed protein to form their body protein. If the quantity and quality of feed protein content is high, it will have a positive effect on the larvae and vice versa. This can prove that tofu dregs waste is able to stimulate the development of BSF larvae and help the effectiveness of BSF larvae in degrading organic waste.

ECD Value

Describes the amount of food eaten by BSF larvae and shows the efficiency of BSF maggots in converting the food they eat into biomass. The higher the ECD value, the higher the efficiency level. When the nutritional content of the feed media is low, it will result in a larger amount of feed being consumed because nutritional needs must be met, resulting in a low ECD value. The ECD value is calculated using the initial weight and final weight of the larvae. The initial weight is obtained from the initial number of larvae seeds given to the processing media after going through the acclimatization stage for 6 days, and the final weight is obtained from the increase in larvae weight after the waste consumption period for 14 days. Data on larval weight are shown in Table 2.

Table 2. Initial and Final Weight Values of BSF Larvae

Reactor	Number of Larval Seeds (g)	Initial Weight (g)	Final Weight (kg)
M1	10	210	1.52
M2	10	207	0.86
M3	10	212	1.76

The conversion efficiency of feed digested by BSF larvae illustrates how efficiently waste is used as feed consumed by BSF larvae. The value of the results from ECD measurements in each reactor shown in Table 4.7 shows that the value in reactor M1 is 10.47%, which consists of 25% rice waste, 25% cucumber waste and 50% tofu dregs waste, then reactor M2 is 5.65 % consists of 50% rice waste and 50% cucumber waste the M3 reactor is 11.67% which consists of 100% tofu dregs waste, of the 3 reactors showing the highest results seen in the M3 reactor with an ECD value of 11.67%, this occurs because the type of waste contained in the M3 reactor is 100% tofu dregs waste, apart from tofu dregs waste it can have a positive effect on the development of BSF larvae, it can also increase the effectiveness of BSF larvae in consuming feed due to the protein and fat nutritional content contained

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in tofu dregs waste is relatively high. Dafri *et al*., (2022), stated that tofu dregs waste can be used as a protein source feed ingredient because it contains high crude protein levels. The nutritional content of protein and fat is the preferred food for larvae, thereby increasing waste consumption (Balhis *et al*., 2022). Dafri *et al*., (2022), stated that tofu waste contains 23.39 crude protein, 19.44% crude fiber, and 9.96% fat. The results of measuring the ECD value in this study prove that tofu dregs waste can stimulate the growth of BSF larvae.

Water Content Value

The results of measuring the final water content of each reactor were used as a comparison of the initial test that had previously been carried out, to determine changes in the water content contained in the initial waste before processing and after processing, which was taken from the excreted material by BSF larvae. The final water content test results can be seen in Table 3.

Table 3. Final Water Content Test

Reactor	Initial Test (%)	Final Test (%)
M1	84	53.43
M2	81.84	58.49
M3	87.39	55.51

The results of the comparative analysis of reactor's initial and final water content tests for each reactor showed a decrease. The M1 reactor with the treatment of 25% rice waste, 25% cucumber waste and 50% tofu dregs waste obtained an initial water content test of 84%, then experienced a decrease of up to 53.43%, in the M1 reactor the final water content reduction results were better if compared to the M2 reactor. The degradation process of waste degradation by BSF larvae can also affect reducing the water content through burning calories, which can increase the temperature, and the heating process occurs, but the type of waste can also be one of the influences on changes in the quality of the water content obtained after the reduction results.

The M2 reactor, with treatment of 50% rice waste and 50% cucumber waste with an initial water content of 81.84% experienced a decrease of up to 58.49%. In the M2 reactor, the resulting decrease in water content after the reduction process was lower when compared to the M1 reactor and M3, this is caused by the type of waste provided, which is related to the reduction process carried out by BSF larvae. The kind of waste in the M1 reactor consists of cucumber waste and rice waste. If we look at the results of the reduction percentage and efficiency of waste conversion by BSF larvae in the M2 reactor, the results are lower when compared to the M1 and M3 reactors, it can be indicated that the reduction process is occurring in the M2 reactor it is less good when compared to the M1 and M3 reactors so that the reduction in water content is also less. The analysis results of the decrease in water content in the M2 reactor have not yet been obtained with accurate analysis results. After the research progressed, it was found that there were a few external problem factors, namely that it rained during the research process, so rainwater entered the M2 reactor processing media.

The results in the M3 reactor with 100% treatment of tofu dregs waste had an initial water content of 87.39, decreasing to 55.51%, in the M3 reactor the highest water content reduction was obtained, this happened because the type of waste given influenced the degradation process by BSF larvae, if the degradation process goes well then the process of reducing the water content will also be good in the excreted material. The decrease in water content in each reactor was caused by an increase in temperature which produced heat energy due to the activity of BSF larvae and microorganisms. (Hakim *et al*., 2017) stated that the initial high-water content of organic waste has decreased. The decrease in water content in the compost is caused by the activity of microorganisms and the activity of BSF larvae which produces heat energy so that compost experiences evaporation and the water content decreases.

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pH Value

The results of the final test measurement of the pH levels of each reactor were used as a comparison of the initial tests to determine changes in the pH levels. The final pH test results can be seen in Table 4.

Table 4. Final pH Level Test

Reactor	Initial Test	Final Test
M1	3.75	6.4
M2	5,6	5.9
M3	3.5	7.1

The results of the comparative analysis of the initial and final pH tests from each reactor showed an increase. In reactor M1 with treatment of 25% rice waste, 25% cucumber waste and 50% tofu dregs waste, the initial pH level test was 3.75 and then increased to 6.4%, and the M2 reactor treated with 50% rice waste and 50% cucumber waste with an initial pH level of 5.6 experienced an increase of up to 5.9%, while the M3 reactor treated with 100% tofu dregs waste had an initial pH level content of 3.5 has increased to 7.1. The results of measuring the final pH levels in the compost from each reactor increased. The pH conditions in this study started with acidic conditions then fluctuated until finally the final sample had a neutral condition. The condition of the leachate in the waste can affect the pH value, the wet condition of the waste will cause the waste to become anaerobic which causes the fermentation process to occur. The ability of most microorganisms to live in anaerobic conditions, utilizing energy that comes from the fermentation process of organic compounds. The use of cations such as ammonium ions from $(NH_4)_2SO_4$ results in an increase in the pH value, (Nadhifah *et al*., 2022). The high activity of microorganisms in waste can result in an increase or decrease in the pH value. stated that the activity of BSF larvae can change organic carbon compounds into organic acids, which is no longer the dominant process and there has been the formation of ammonia compounds which can increase the pH value.

C/N Ratio Value

The results of the final test measurement of the C/N content of each reactor were used as a comparison of the initial test that had previously been carried out, to determine changes in the C/N ratio contained in the initial waste before processing and after processing which was taken from the excreted material by BSF larvae. The final C/N ratio test results can be seen in Table 5.

Table 5. Final C/N Ratio Test Rate

Reactor	Initial Test			Final Test		
	Carbon (C%)	Nitrogen (N%)	C/N Ratio	Carbon (C%)	Nitrogen (N%)	C/N Ratio
M1	56.83	2.51	22.67	41.49	3,482	11.92
M2	57.2	1.42	40.34	45.79	2,909	15.74
M3	55.96	2.89	19.34	46.13	3,263	14.14

The results of the comparative analysis of the results in the M2 reactor showed that the initial concentration test showed a carbon content value of 57.2%, which decreased to 40.34%, and the initial nitrogen content was 1.42%, then increased after the composting process to 2.909%, in the M2 reactor, the ratio was reduced. C/N is quite high when compared with M1 and M3 reactors. The decrease in the C/N ratio in the M2 reactor was influenced by a high increase in nitrogen content. The high level of nitroget in the M2 reactor is due to the degradation process of quite a large amount of organic carbon and this process produces nitrogen, so that the nitrogen content increases. The results in the M3 reactor showed that the initial concentration test showed a carbon content value of 55.96%, which decreased

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to 46.13%, and the initial nitrogen content was 2.89%, then increased after the composting process to 3.263%, in the M3 reactor, the ratio was found to decrease. C/N is lower when compared to the M2 reactor and not much different when compared to the results of decreasing the C/N ratio in the M1 reactor, this is due to the treatment, variations in the type of waste and the composition used, there are the same types of waste.

All content test results in each reactor show that the carbon content value has decreased. The decrease in carbon content is caused by degradation activities carried out by BSF larvae which consume the organic carbon content in the waste. The nitrogen content in each reactor also increased, this was due to the degradation activity of the larvae resulting in the formation of ammonia gas which could increase the nitrogen content in the compost. (Firdausy *et al*., 2021) stated that the increase in nitrogen content was due to the formation of ammonia gas in the samples during the waste protein degradation process by BSF larvae and microorganisms. The decrease in the C/N ratio is slightly lower to the M2 reactor, this is due to the increase in the amount of nitrogen content. The increase in nitrogen content in the M1 reactor can be influenced by 2 (two) factors, namely the increase in nitrogen content created from the degradation of carbon content by BSF larvae and the relatively high protein content contained in tofu dregs waste which can influence the increase in nitrogen content. According to (Nadhifah *et al*., 2022) the presence of protein content in the sample also influences the increase in nitrogen content in the sample. Amino acids are the structural units of protein, with the help of heterophic bacteria they will be converted into ammonia. However, the increase in nitrogen content in the M1 reactor is also not too high when compared to the increase in nitrogen found in the M2 reactor, this is due to the process where the larvae consume protein. and utilize a small amount of nitrogen as a process for metabolizing the body and converting it into biomass so that the increase is not too high.

High and low carbon and nitrogen content in organic waste are 2 (two) factors in determining the C/N ratio of organic waste. The activities of BSF larvae and microorganisms influence the amount of carbon and nitrogen levels. In this activity, BSF larvae and microorganisms consume carbon in organic waste which can produce nitrogen content in organic waste. The decrease in the C/N ratio in the composting process in each reactor was caused by changes in carbon and nitrogen content. The value of carbon and nitrogen content in the M1 reactor was obtained from the initial content test with a carbon content value of 56.83% which decreased to 41.49%, then the initial nitrogen of 2.51% increased after the composting process to 3.482%, in the M1 reactor it obtained initial and final C/N ratio tests for each reactor showed a decrease. The results of the M1 reactor with treatment of 25% rice waste, 25% cucumber waste and 50% tofu dregs waste showed an initial C/N ratio test of 22.67, then decreased to 11.92. The M2 reactor with treatment of 50% rice waste and 50% cucumber waste obtained a C/N ratio value of 40.34, decreasing to 15.74. The results of the M3 reactor with 100% tofu dregs treatment showed that the initial C/N ratio test was 19.34, decreasing to 14.14.

CONCLUSION

The conversion efficiency value of feed digested by BSF larvae, in M1 which gets an ECD value of 10.47%, then reactor M2 gets an ECD value of 5.65%, while in the M3 reactor the highest ECD value was obtained with a value of 11.67%. The final water content of organic waste is a range of 53.43-58.49%. The final pH value in the range of 5.90-7.10. The C/N ratio final in a range of 11.92-15.74.

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