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The Effect of Leaf-Waste Type and Bioconversion Ability Based on Feed Conversion Ratio in Black Soldiers Fly Larvae (*Hermetia illucens*, L.)

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ABSTRACT
The Black Soldiers Fly (Hermetia illucens) life cycle is unique. The uniqueness lies in the life of the larvae until the pupae and metamorphosis become relatively clean flies, do not like smelly media and tend to be in a moist to dry medium. Unlike some other types of flies, the BSF life cycle brings more advantages than disadvantages. There are various problems related to the ability of BSF larvae to decompose organic waste. An investigation was needed to determine the ability of leaf waste decomposition in the environment which is quite abundant and its potential has not been calculated. Four types of leaf waste that will be tested, namely categories A, B, C, D including A (Ketapang / Ficus Lyrata, **FF**), B (Markisa / Passion fruit / Passiflora edulis, **FM**), C (Kelengkeng / Longan / Dimocarpus longan, **FK**), D (Glodhogan pecut / Polyalthia longifolia, Sonn., **FG**). Meanwhile, E as control was an exclusive basic feed. The composition of the ratio of [medium: basic feed] BSF in each category A, B, C, and D as a medium for larval rearing, consists of: (80:20), (60:40), (50:50), (40:60) and (20:80) %. Each treatment had 4 replications. The place of maintenance is a plastic tub covered with a plastic net and the initial weight of the media composition is 500 grams. Each tub was maintained by larvae with an average weight of 20 grams/tub until they reached the pupal period. The basic feed was fermented soft bran. The parameters observed were: the bioconversion ability of BSF larvae based on the Feed Conversion Ratio (FCR). Data analysis using a completely randomized design with a nested design on 2 independent variables was carried out using SPSS version 19 software. The results showed that the type of leaf waste and the basic feed ratio had a very significant effect (P <0.01) on the ability of bioconversion based on the Feed Conversion Ratio (FCR) of BSF larvae, and the highest was in the treatment of Passion fruit waste with ratio 50: 50%.

Keywords: *Variation, ratio, waste, leaves, larvae, BSF.*

1. INTRODUCTION

Insect-based organic waste can be processed using Black Soldier Fly (BSF) larvae, Hermetia illucens, L. (Diptera: Stratiomyidae). BSF is currently not popular and has not been studied in depth in Indonesia. BSF larvae are the subject of innovative use as a sustainable method for organic waste management that can reduce the burden of landfill waste [1] and [2]. Also, intensive management can open new economic opportunities that are beneficial for urban residents and small-scale entrepreneurs in developing countries [3].

BSF larvae are very active in digesting various organic materials, such as fruits and vegetables, market waste, kitchen waste, fish waste, palm oil cake, and livestock and human manure, so they are classified as bioconversion agents [4]. The ability of BSF larvae to reduce organic waste has been reported to be 66.4–78.9%. The final development stage of larvae, which is called prepupa, can be self-harvested, resulting in high added value [5], which contains 40% protein and 30% fat which can be used as fish feed and livestock substitute for a fish meal [3].

A normal BSF female fly is capable of producing eggs ranging from 185-1235 eggs [6]. Other literature states that a female takes 20-30 minutes to lay eggs with a total egg production of between 546-1,505 eggs in the form of egg mass [7]. Egg mass weight ranges from 15.8-19.8 mg with individual egg weight between 0.026-0.030 mg. The peak time for egg-laying is reported to be around 14.00-15.00. Female flies are reported to lay eggs only once during their lifetime, after which they die [8]. It is further stated that the number of eggs is directly proportional to the body size of adult flies. Female flies that have a larger body size with wider wings tend to be more fertile than flies with small bodies and wings [9]. The number of eggs produced by large flies is more than that of small flies. Besides, the humidity was also reported to affect the laying capacity of BSF flies. About 80% of female flies lay eggs in conditions of more than 60% humidity and only 40% of female flies lay eggs when the humidity conditions are less than 60% [7].

Holmes, et al. [10], compared five substrates in the pupal stage, namely sawdust, soil, humus, sand and not using substrates. The pupae were maintained on the sand and humus substrate longer than on the soil and sawdust substrate. The pupal stage without substrate runs the fastest because it reduces the risk of predators or environmental threats. However, this condition causes the hatchability of the pupa to become an imago (adult fly) is lower than the others. This is presumably because the energy stored during larvae is mostly used to defend itself from inappropriate environmental conditions. Female pupal weight is on average 13% heavier than male pupa weight [8], and after 14 days, the pupae develop into adult flies (imago).

The reduction of organic waste by larvae of Hermetia illucens is an attractive recycling technology and has a high economic potential [5]. Hermetia illucens larvae are considered beneficial because they are able to utilize organic waste from both animal, plant, animal, and human feces as a source of food and increase the recycling value of organic waste. Several studies have also shown that Hermetia illucens larvae could degrade organic waste, both from animals and plants, better than other insects that have been studied [11]. Hermetia illucens larvae are also known to have a very varied range of food types. Hermetia illucens larvae can eat animal waste, meat, fruit, restaurant waste, kitchen waste, and various other types of organic waste [12].

Bioconversion is a process by involving microorganisms such as yeast, fungi, and bacteria or alternatives to terrestrial invertebrates such as insect larvae to convert organic waste into products of higher value. The bioconversion concept is an interesting solution that can solve the problem of organic waste management. Bioconversion is a continuous process that utilizes insect larvae to transform organic waste. Furthermore, these insect larvae convert nutrients from waste and are stored as biomass [13].

Reduction of various organic waste by larvae Hermetia illucens has been studied by researchers namely the reduction of human waste material by 51.3% and 84.9% reduction in poultry feed [2]. Furthermore, the reduction of cow manure from 33 to 58% and chicken manure by 50% [14] and [15] and the reduction of city organic waste from 66 to 79% [5] and [13]. Residue from larvae Hermetia illucens used as compost and has high levels of nutrients for use as fertilizer and soil amendment. The rate of waste consumption by larvae Hermetia illucens varies according to the type of waste, moisture content, the number of larvae, size of larvae, and temperature [13] and [16].

Feed Conversion Ratio (FCR) is the ratio between the amount of feed given and the increase in body biomass produced. The FCR value is the ratio between feed consumption and body weight gain obtained within a certain period. The FCR value through the formula below should ideally be close to 1 and always above 1. The FCR is usually used to measure livestock productivity, although other animals can also apply. The FCR formula can also be calculated in% units, so a high percentage will indicate a high level of feed use efficiency [17]. According to Effendi [18], one of the formulas for calculating the FCR value is as follows:

$$FCR = \frac{F}{Wt-Wo}$$

Information:

F = *Amount of feed consumed during the maintenance period (kg)*
Wt = *Final biomass (kg)*
Wo = *Initial biomass (kg)*

Currently, waste management was still focused on the final waste processing area (Tempat Pembuangan Akhir = TPA) without going through the 3R (reduce, recycle, reuse) process involving community participation. This condition is a major factor in the burden of the landfill being heavy and the life of the utilization was getting shorter. BSF larvae have not been fully utilized innovatively and sustainably manner for organic waste management which could reduce the burden of TPA waste, as well as to be able to open new economic opportunities that were beneficial to city residents and small-scale entrepreneurs. The nutrient content in BSF larvae was very high, could be used as a good natural feed raw material, but it was still unfortunate that these feed components are still very expensive for the size of fish breeders and keepers. The basic problems in this research were the composition of leaf waste types in the rearing medium and the basic feed ratio of BSF larvae could affect the Feed Conversion Ratio (FCR). This study aimed to determine the effect of the composition of the type of leaf waste in the maintenance medium and the basic feed ratio on the.

BSF larvae bioconversion ability based on FCR.

2. METHOD

2.1. Research design

Four types of leaf waste that will be tested: A (Ficus), B (Passion fruit), C (Longan), D (Olyanthea), and E as a control in the form of 100% basic feed. The ratio of media and basic feed of BSF in each category and each treatment was have 4 replications. The study population was all larva of Black Soldiers Fly / BSF (Hermetica illucens). The research sample was taken using purposive sampling, by taking healthy BSF larvae from hatching 4 grams of eggs at the age of 10 days after incubation with average initial biomass of 20 grams of larvae/tub. The place of maintenance is a 36 x 26 x 6 cm plastic tray on a rack covered with a plastic net and with a total weight of the media composition was 500 grams. Maintenance was ended after most of the larvae became pupae (± 21 days after egg incubation). The larva cage was in the form of 2 iron frame racks, each consisting of 4 levels with a size of 2 X 0.6 X 2 meters.

Independent Variable: Types of leaf waste and the ratio of [leaf waste types: basic feed]. There are 4 types of leaf waste were selected to be tested. The types of leaf waste were taken from around which had quite a lot of plant stands, namely: Ficus (Ficus bengalis), FF; Passion fruit (Fasiflora sp.), FM; Longan (Dimocarpus longan), FK; Polyalthia (Polyalthia longifolia), FG; and the basic feed were made as a mixture of 1 kg of fine fermented bran by adding 500 ml of clean water, 1 bottle of yogurt and 1 sachet of chicken flavored, and broiled in anaerobic conditions for 7 days. Dependent Variable: Bioconversion based on feed conversion ratio (FCR).

Tools: Cages with mosquito staining walls size 2 X 0.6 X 2 meters, thermometer, hygrometer, media tub in the form of plastic trays size 35 X 26 X 6 cm (44 pieces), analytic balance 100-gram capacity (0.1 mg accuracy), latex gloves, rulers (1mm accuracy), stationery, digital cameras, and Nikon Imaging System Stereo Microphotography. Material: BSF larva (Hermetia illucens), fine bran, fermented milk, chicken flavor, clean water, leaf waste of various plant categories (A, B, C, D).

2.2. Research Procedure

BSF egg preparation. BSF eggs were purchased from the KOLONI BSF INDONESIA breeding agent, 4 grams, incubated in a plastic tub size 45 X 36 X 15 cm covered with fine plastic net. The maintenance media were arranged according to the composition as the independent variables that have been determined above in 4 replications, namely:

a. (80% crop waste + 20% basic feed),
b. (60% crop waste + 40% basic feed).
c. (50% crop waste + 50% basic feed),
d. (40% crop waste + 60% basic feed),
e. (20% crop waste + 80% basic feed),
f. (100% basic feed) as control.

The preparation of maintenance media consisted of waste from various plant categories (A, B, C, D) from around the environment which had been finely chopped with a chopper and brooded with a fermenter for 7-14 days. BSF Larvae Maintenance carrier out by prepared BSF eggs in the same period of laid, hatched in the hatching medium consisting of chicken bran/rice bran - yogurt and chicken flavored, brooded anaerobically for a week. After days-5 of post-hatched larvae into plastic trays containing media according to the intended treatment. The total biomass of BSF larvae per tray was 20 grams. The day and date of the start of maintenance were recorded. The addition of basic feed according to the ratio determined along with introducing BSF larvae. The larvae were placed on the surface of the middle of the media, after which the larvae would enter the media by themselves. Cover the media tub with food wrapping paper that had been cut to the size of the media tub. Checked the temperature and humidity of the media on the media every 3 days during the day. Addition of basic feed added 5 grams/tub on the first and second 3 days into each tub of the treatment media. The total biomass of BSF larvae was weighed at the beginning and the end of rearing. Maintenance was ended when all or most of the larvae in each treatment tub had entered the pupa period which had turned blackish brown. The day and end date of maintenance are recorded.

Data collected according to the type of data taken as follows: Data on BSF larval biomass gain was weighed twice during the study, namely the beginning and end of maintenance from the total larvae in each treatment medium using a digital analytical balance Model I-2000 and DS-22. The larvae were cleaned first from the included media before weighed. Media weight data before and at the end of maintenance were recorded, including additional basic feed given on the first and second 3 days during the study.

The study was concluded on the 21-st day of maintenance. According to Effendi [18], the FCR value can be calculated using the following formula:

$$FCR = \frac{\text{End biomass} - \text{Initial larval biomass (grams)}}{\text{Initial} - \text{End media weight (grams)}} \times 100\%.$$

Environmental data such as the temperature and humidity of the media were measured every 3 days at 11.00 WIB. Sprayed water was done when the media had a little dry. The composition analysis of the maintenance media was carried out at the LPPT UGM Yogyakarta Laboratory, covering levels of Crude Fiber, Nitrogen, and Carbon. Data analysis of BSF larval biomass gain, a developmental period of larvae into pupae, FCR used the nested completely randomized design with 2 independent variables and the Duncan Multiple Range Test (DMRT) were carried out with SPSS Version 25 software. The developmental period data of larvae into pupae were analyzed with the *Kruskal Wallis Test*.

3. RESULT

The effect of the type of leaf waste on biomass gain was highest in the treatment with passion fruit leaf waste, although this increase was still lower than that of control. The highest increase in larval biomass at the ratio [type of leaf waste: basic feed] 50: 50%. Although this biomass gain was lower than the control which consisted of 100% basic feed.

Table 1. Increase in Larva Biomass based on the type of leaf waste treatment

Increase in Larvae Biomass - Pupa			
Types of Leaf Waste	**Mean**	**N*)**	**Std. Deviation**
FF	78.0625	24	31,19218
FM	110,1958 *	24	21.33143
FK	104,2000	24	24,88825
FG	101.8167	24	23,72725
Control	123,3000 *	16	7,46440
Total	98,5688	96	27.98306

**)N = number of treatment tub measured*

Table 2. Increase in Larvae Biomass based on Ratio [Type of Leaf Waste : Basic Feed] Treatment

Increase in Larvae Biomass - Pupa			
Ratio [Leaf Waste : Basic Feed] (%)	**Mean**	**N*)**	**Std. Deviation**
80/20	76.8437	16	12,17511
60/40	91.8938	16	16,53185
50/50	104.8313 *	16	15,06531
40/60	100.3625	16	26.70752
20/80	94,1812	16	47,67223
Control	123,3000 *	16	7,46440
Total	98,5688	96	27.98306

**)N = number of treatment tub measured*

Leaf waste reduction was found in Ficus, mostly consumed by BSF was Ficus leaf waste (FF) easiest to digest by BSF larvae. Meanwhile, it could also be seen that the highest reduction in media weight was found in the control treatment (basic feed), that the digestibility level of the media in the control was the higher compared to other media. This digestibility level will further be seen in its' effect on the FCR of each leaf waste.type.

The highest FCR figure shows the efficiency level of the unit weight of the rearing media that BSF larvae use to convert into biomass gain. Referring to the FCR formula on page 12 above, the feed efficiency that will be converted to an increase in larval biomass is indicated by the higher% number. The highest FCR in the treatment of leaf waste types was found in Passion Fruit (FM). This can be seen more clearly in the bar chart of Figure 1. FCR in the treatment of leaf waste types obtained 55.17%, is the highest number compared to FCR of other types of waste.

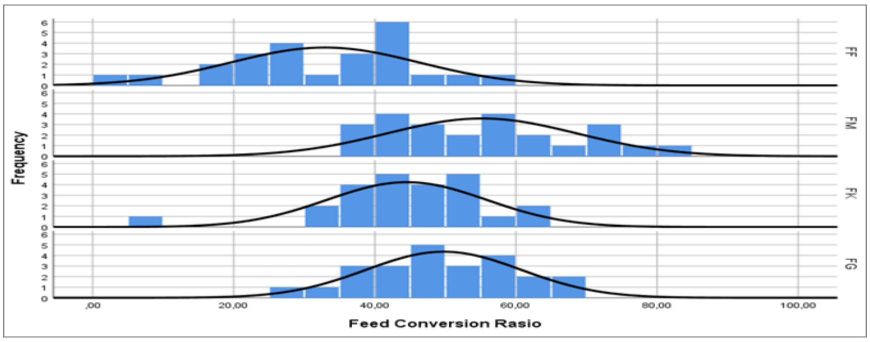

Figure 1 The Bar Chart of the Effect of Leaf Waste Types on *Feed Conversion Ratio* BSF larvae

From the ratio [type of leaf waste : basic feed], the highest FCR 52.04%. was achieved in the treatment with a ratio of 80: 20%. It could also seen in Figure 2:

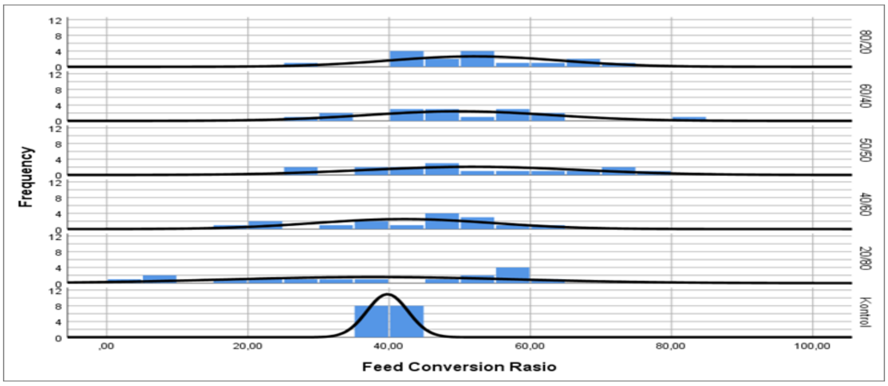

Figure 2. The Bar Chart Effect of Ratio [Type of Leaf Waste: Basic Feed] on the BSF Larva Feed Conversion Ratio

Overall, the highest FCR was at The treatment interaction between types of leaf waste and the ratio [Type of Leaf Waste: Basic Feed] was found in the type of Passion Fruit (FM) leaf waste at a ratio of 50:50% of 65.66%. The effect of leaf waste type treatment and the ratio [type of leaf waste: basic feed] was significantly affected (P <0.01) the bioconversion ability of BSF as seen from the contribution to the FCR value.

4. DISCUSSION

The highest increase of Hermetia illucens larvae biomass in the treatment of leaf waste types were found in the Passion Fruit (FM) treatment. This can be due to the presence of crude fiber compounds, especially high lignin in the treatment of Ficus (FF), Longan (FK), and Olyanthea (FG) leaf waste treatment. This is by following the statement of Yunilas [19] which states that the high lignin content causes low digestibility and low larval biomass. The success of fermentation in the process of preparing larval rearing media can also affect the ability of the larvae to digest Passion fruit (FM) leaf waste. Fermentation in Fiscus (FF), Longan (FK), and Glodogan (FG) with high lignin levels will be more difficult to ferment. This is by following the statement of Supriyatna and Putra [20].

Another supporting research is the research conducted by Mangunwardoyo, *et al*. [21], that larvae were given fermented straw produced higher biomass and conversion value compared to larvae given straw substrate without fermentation treatment. This shows that the fermentation process facilitates the digestion process by the larvae which will later be converted into biomass.

Efforts to increase the benefit value of various types of leaf waste, both Fiscus, Passion fruit, Longan, and Glodogan as a mixture of BSF larvae feed ingredients can be done by fermentation. Fermentation is a process in which microorganisms produce enzymes that can convert complex organic materials such as proteins, carbohydrates, fats into molecules that are simpler and easier to digest [6]. The factors that determine the success of the fermentation process are temperature, pH, particle shape and size, inoculum dose, and fermentation time [22].

The FCR in this study is the ability of the Hermetia illucens larvae to utilize the mass size of the maintenance media in each type of treatment. The mass reduction from the start to the end of the maintenance will affect the size of this conversion value (FCR). The amount of maintenance media remaining on the level can also indicate a high or low FCR value. According to Stickney [6], feed conversion (FCR) is how many grams of increase in the biomass of Hermetia illucens larvae produced from some feeds given in the same weight unit. The higher the percentage of feed conversion, the greater the feed utilization efficiency.

The highest FCR value in the treatment of leaf waste types was obtained in Passion Fruit (FM), treatment with the ratio [Type of Leaf Waste: Basic Feed] obtained the highest number at 80:20%. Meanwhile, the specific treatment between the type of leaf waste and the ratio [Type of Leaf Waste: Basic Feed], the highest FCR number was obtained for the type of Passion Fruit (FM) leaf waste at a ratio of 50:50%. The good ability of the Hermetia illucens larvae in digesting the maintenance media in the form of passion fruit leaf waste combined with the basic feed ratio affects the percentage of FCR. Feed conversion can show the total feed consumed to increase body weight by one unit [24]. The higher the feed conversion value means the more efficient it is used or the less feed is needed to increase body weight by one unit. According to Suciati and Faruq [25], the quality of feed is influenced by the digestibility and absorption of animals to the food consumed. The greater the FCR percentage, the better the feed quality, but if the FCR value is low, the feed given is of poor quality. The low feed conversion ratio is generally caused by poor feed quality.

The utilization efficiency of BSF larval rearing media that is not good can be seen from the low conversion value, namely the higher the feed conversion value, the higher the efficiency of feed use will also be. Feed conversion is very well used as a guideline for production efficiency because it is closely related to production costs, and is one of the efficiency parameters from an economic side [26].

5. CONCLUSION

The highest FCR in the treatment of leaf waste types was found in Ficus (FF). The ratio [type of leaf waste: basic feed], the highest FCR (52.04%) was achieved in the treatment with a ratio of 20: 80%. The interaction very significant (P <0.01) affected the FCR of BSF with the highest (65.66%) from Passion Fruit (FM) waste type with a ratio 50:50 %.

AUTHORS' CONTRIBUTIONS

Ciptono and Suhandoyo designed and directed the project; Ciptono, Suhandoyo nad Tri Harjana performed the experiments; Ciptono and Rizka Apriani Putri feeding analysed ; Suhandoyo and Tri Harjana made the formula of feeding media; Ciptono, Suhandoyo and Rizka Apriani Putri developed the theoretical framework and references study; Suhandoyo, Tri Harjana and Rizka Apriani Putri wrote the article.

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