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Decomposition Characteristics of Organic Solid Waste from Traditional Market by Black Soldier Fly Larvae (*Hermetia illucens L.)*

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Abstract

The Ministry of Environment of Indonesia in 2017 stated that the majority of Indonesia's waste is the organic fraction, of which the percentage was approximately 60%. One of the technologies to reduce organic waste is using decomposition process. Waste treatment using black soldier fly larvae (BSF) has many advantages including several products that can be utilized such as larvae protein and compost. The objective of the research is to obtain the decomposition characteristics of the organic solid waste from the traditional market by using Black Soldier Fly larvae (BSFL). The experiment was carried out in a laboratory and household scale. Activities of the research involved the test of the installation system of the decomposition process, a test of the larvae protein content, and the analysis of decomposition result quality. The average of the moisture contents of the sample was in the range of 76-96%. Reduction percentage in the sample ranged from 41-63%. WRI (Waste Reduction Index) of the samples ranged from 2.74-4.20. FMCR (Fresh Matter Consumption Rate) was about 20-44 mg/larvae/day. ECD (Efficiency of Consumption of Digested Feed) was in between 3-11%, whereas the survival rate was 15-100%. The protein content was found from 12 days of larvae's age, i.e. 36.4%. After 30-days decomposition process, the results met the national standard, namely SNI 19-7030-2004, except for the C/N.

Keywords: black soldier fly larvae, decomposition, organic, protein, reduction.

INTRODUCTION

Waste is a part of an entity that cannot be used, unpleasant that in general comes from the activity carried out by human (including industrial activity), but is not biologically (human waste is not included) and commonly is in solid form [1]. The Ministry of Environment of Indonesia in 2017 stated that the majority of Indonesia's waste is the organic fraction, of which the percentage was approximately 60%. One of the existing technologies to process organic solid waste is composting, i.e. decomposition of materials by microorganism inside the materials itself with the aid of air [2].

Waste recycling is one of many solutions to decrease the generated waste with minimum cost and can be managed either by the formal or informal sector [3]. The utilization of black soldier fly (BSF) larvae to decompose organic material is an example of waste management. In previous studies, the BSF larvae has been identified that they can decompose organic waste, in which the larvae extracts the energy and nutrient of organic waste [4]. The BSF larvae is identified as an organism that originated from an egg of black soldier fly (BSF) and known as a break-down agent, due to its behaviour of consuming organic material of waste [5]. Existence and durability of BSF larvae are better than an earthworm, which is currently developed as a composting agent [6]. This method is suitable to apply in an urban setting that is known for its high rate and volume of organic material production [7].

The reduction method of organic waste that was used is the aerobic one with the BSF larvae (*Hermetia illucens L.*). The organic waste that was set as the sample consisted of mustard greens, cucumber, banana, carrot, avocado, guava, tomato, and aggregate. This system is proposed to reduce or even to eliminate the transport of organic waste from traditional markets to the final disposal site. Besides, the BSF larvae gained from the experiment could be an essential component of livestock and poultry feed. Utilization of glucose and xylose from the BSF larvae's feed can be converted as bioethanol and biodiesel through the fermentation and digestion process due to its high lipid content. From 200g rice stalk as a feed for BSF larvae produced 10.9g bioethanol and 4.3g biodiesel [8]. Using corn stover and carrot, 200g and 29.25g, respectively, formed 1.76g biodiesel, 6.55g protein feed, and 111.59g bio-organic fertilizer by digestion from yellow mealworm and BSF larvae for the second stage production [9]. Biogas can be formed from BSF larvae production that uses cattle manure [10]. BSF larvae can be used as a protein-based material since moisture indicator always be a critical factor in protein-based material. Further, the applications of BSF larvae could be utilized as covers of lamps, covers of electrical parts/switches and disposable plastic products [11]

METHODOLOGY

This research was conducted in February-May 2018. The decomposition process was undergone in a composting house in Margajaya Village of Bogor Municipality. Quality of compost resulted from the decomposition process was analysed in The Soil Laboratory of SEAMEO BIOTROP, Bogor. The research instruments used in the experiment were wet bulb and dry bulb thermometers (range 0-100˚C), hammer, measurement band, saw, balance (0.1 gr), hand gloves, masks, ruler and a laptop equipped with Microsoft Excel. Materials used in the research were organic solid waste from a traditional market, BSF larva, acrylic board, gauze pads, trash bag, iron wire, plastic rope and nails.

The sample water content was determined by using the gravimetric method, in which the water was heated at 105 ºC for 24 hours. The pH of the initial samples was determined by using the pH meter. In contrast, the final pH was calculated by using the potentiometric technique, considering that the condition of the sample, which were already dry. The air temperature was recorded for 15 days, where the measurement was carried out twice a day in the morning and afternoon. The air relative humidity (RH) was obtained graphically from the psychrometric chart based on the air temperature data. The larvae weight was measured every three days for 15 days. However, the measurement was only done for the representatives, which are 10% of the total population in each reactor [12][13]. At the beginning of the research, the organic waste that is planned to be given to the BSF was determined, which was 40 mg/larva/day of dry material. The flowchart diagram of the research is presented in Figure 1.

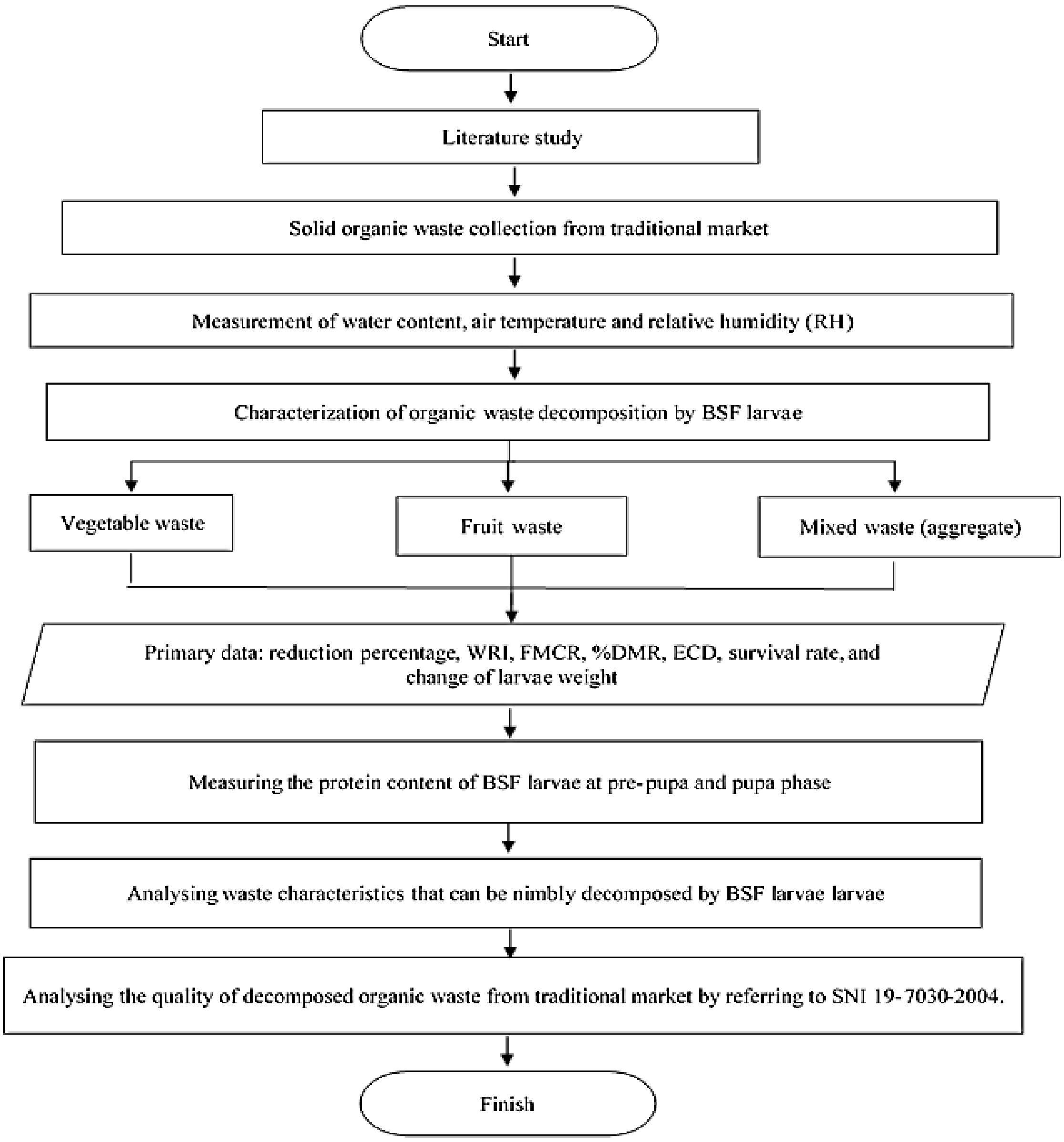

Figure 1. Research flowchart

To determine the waste that is nimbly decomposed by the BSF larva, several calculations were undergone to identify it, i.e. the transformation larva's weight, reduction percentage, WRI (waste reduction index) and FMCR (fresh matter consumption rate). The larva's preference of a particular given organic waste was measured based on the ECD (consumption efficiency of digested organic waste) and survival rate. Defined the waste reduction rate of BSF larvae as Waste Reduction Index (WRI) as presented in Equation 1 [3].

$$WRI = \frac{D}{t} x\, 100\% \qquad (1)$$

Remark:

WRI = waste reduction index (%/day)

D = waste reduction rate (-)

t = acquired time for waste decomposition (day).

Daily consumption rate of waste is calculated based on the dry weight of the organic waste, which is the fresh matter consumption rate (FMCR) that is presented in Equation 2 [3].

$$FMCR = \frac{a/b}{c} \qquad (2)$$

Remark:

FMCR = daily consumption rate of fresh organic waste (mg/larva/day)

a = amount of added waste (mg)

b = duration of addition (days)

c = amount of larvae (larva).

Based on the total mass of organic waste that is added during the larvae phase and weight of waste residue at the final of the cycle, the Dry Matter Reduction (DMR) is calculated in per cent by using Equation 3.

$$\%DMR = \frac{j-k}{k} x 100\% \qquad (3)$$

Remark:

% DMR = value of reduced dry material

j = initial dry weight of organic waste

k = final dry weight of organic waste

The DMCR (dry matter consumption rate) that is used in the design of the planned decomposition facility is calculated by using Equation 4.

$$DMCR = \frac{FMCR\ x\ \%DMR}{100} \qquad (4)$$

Remark:

DMCR = daily consumption rate of waste (dry material)

FMCR = daily consumption rate of fresh organic waste

%DMR = per cent of reduced dry material.

The efficiency of conversion of digested feed is the efficiency of organic waste conversion that is digested by the larvae during the nurturing period, in which the unit is mg/larva/day. The ECD value is calculated based on Equation 5 [14].

$$ECD = \frac{B}{(I-F)} x 100\% \qquad (5)$$

Remark:

ECD = consumption efficiency of digested organic waste (%)

B= larva's weight addition during the ingesting period (mg)

I = amount of consumed organic waste (mg)

F = residual weight of organic waste and excreted material (mg).

The survival rate is the amount of surviving larvae compared to its amount at the initial stage, in which the population's value was measured in percentage [15]. The survival rate was calculated by using Equation 6.

$$SR = \frac{y}{z} x 100\% \qquad (6)$$

Remark:

SR = survival rate (%)

y = amount of surviving larvae at the final period of the experiment (larva)

z = amount of larvae at the initial period of the experiment (larva)

The utilization of the BSF larvae as livestock feed has a significant benefit regarding the protein level that is contained in the BSF larvae itself. The measurement of the BSF larva's protein level was analysed when it reaches the age of 9, 12, 16, 23, and 30 days, based on the stages of the larvae metamorphosis (larva, pre-pupa, and pupa). In this study, the measurement of the protein level was carried out in the laboratory of SEAMEO BIOTROP by using the Kjeldahl method. The final result of the decomposition is the transition of the organic waste material by the microorganism and BSF larvae at a specific temperature into simple organic material, in which the characteristic is a compost-like stable material. The physical parameter that was observed including temperature and colour, while the parameter that was benchmarked of the decomposed organic material's quality were the total N, C-inorganic, P_2O_5, C/N ratio, K_2O, Co, Zn, Ca, Mg, Fe, and Mn. The final step of the analysis was comparing the compost produced from the biodegradation process carried out by BSF larvae with the relevant national standard, namely SNI 19-7030-2004 on the quality of compost. By doing so, the more effective and efficient solid waste decomposition process to produce compost like material could be obtained.

RESULT AND DISCUSSION

Measurement of pH and Water Content

There were eight samples of biodegradable organic waste, i.e. wastes of mustard green, cucumber, banana, carrot, avocado, guava, tomato as well as waste as mixed waste called as an aggregate. To obtain the initial water content, the sample material was undergone by heating it at 105°C for 24 hours. The suggested optimum water level is 60-90% [3]. No special treatment was exposed to the sample to keep it close to the original condition in the traditional market. Substrates that are used for feed in BSF larvae production should be ensured from contamination such as heavy metal and pesticides [16]. Samples were then separated based on their types since the initial picking in the traditional market. The result of the water content measurement is presented in Figure 2.

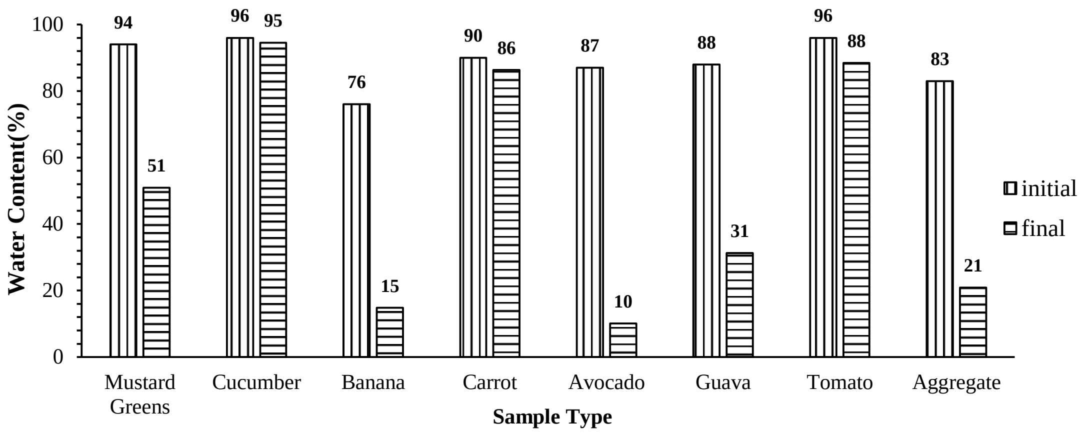

Figure 2. Water content of organic waste

Based on Figure 2, the average water content of all samples is approximately 89.5%. The measurement of the initial water content shows that it ranges in between 75-96%, in which the lowest water content was found in a banana. Contrary, the samples with the highest water content were tomato and cucumber. The purpose of the measurement of the pH value and water content at the final stage was designed to investigate the sample last condition. The comparison of the pH value measurement at the initial and final condition is presented in Figure 3.

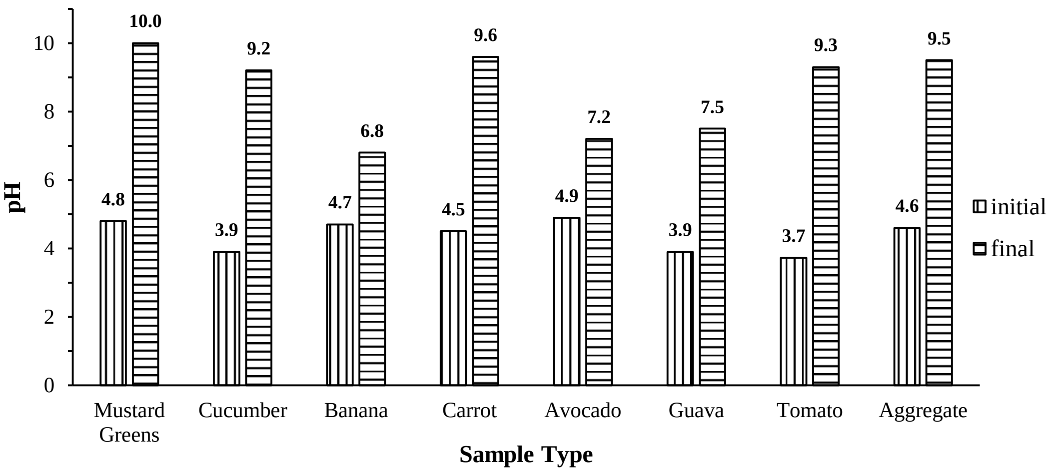

Figure 3. pH value of the sample before and after the decomposition process

The BSF larvae possesses a significant high range of pH tolerance. Thus it can survive in an extreme environment [17]. The high intensity of microorganism activity that occurred in the waste can generate either increase or decrease of pH value [18]. Most microorganisms can live in an anaerobic condition by making use of the energy that is generated from the fermentation process of the organic compound.

As shown in Table 3, the pH value is ranging from 3.7-4.9. The avocado sample is the one that was identified with the highest pH value, i.e. 4.9. Then, the lowest pH value can be found in the tomato sample, i.e. 3.7. There are some possibilities for the bacteria and fungi to grow so that the degradation process by the microorganism can occur as well. The fungus can be found in increasing waste, which is the pH values is 5.6, but it can still survive until the pH values reach 2.0-9.0 [19].

Air Condition in Research Site

The measurement of temperature and relative humidity of the research site was carried out by using both wet bulb and dry bulb thermometers. Based on the observation, the average temperature was 30°C, while the average relative humidity was 75%. The result also shows that the breeding site, i.e. the composting house in Margajaya is suitable enough for the breeding of BSF larva, due to its condition that is close to the optimum state of the larvae growth, which is between 30-36°C [4]. In contrast, the optimum relative humidity is in between 60-70% [20].

Mass Growth of Larva

During the pre-pupa and fly stage, the BSF will stop ingesting and start to make use of the reserved fat as the source of energy [3]. The measurement of the larvae mass is presented in Figure 4.

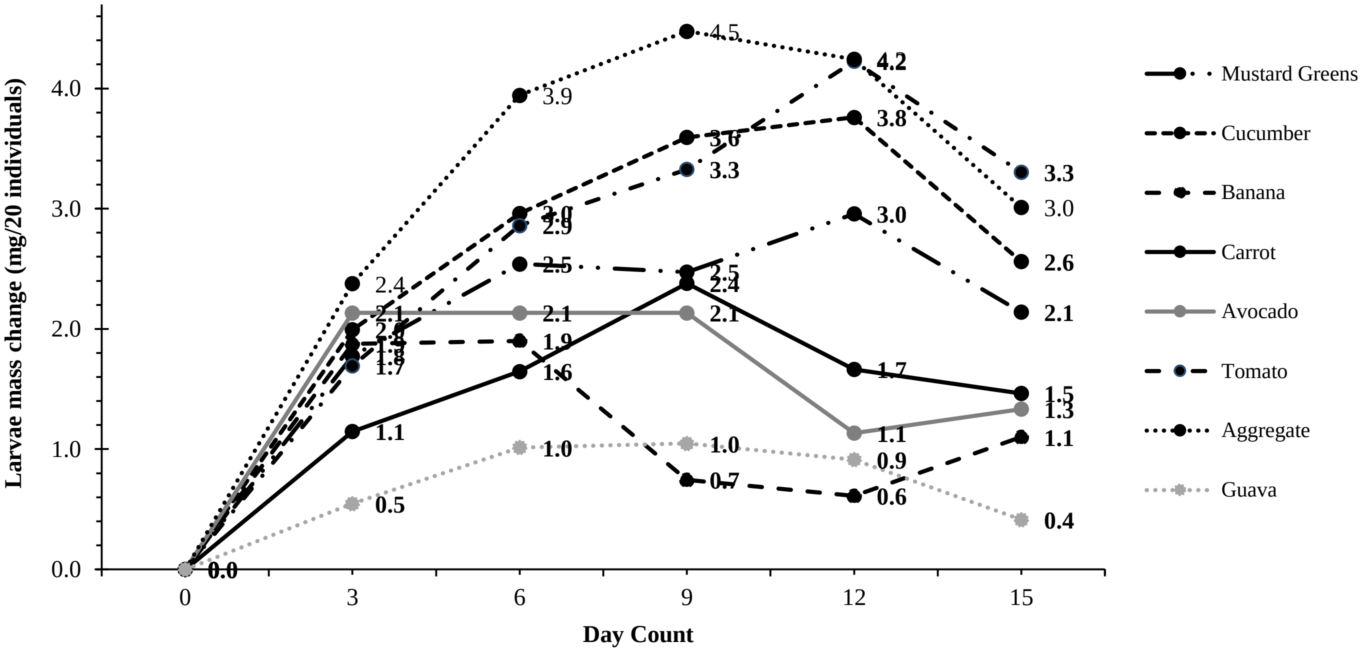

Figure 4. Larvae mass change in selected waste sample

It is shown in Figure 4 that the peak of the larvae growth, in which it weighted 4.5 gr, is found in the aggregate sample. When the pre-pupa develops faster, the mass of the larvae shrinks due to its behaviour that does not ingest and takes away the restored nutrition from its own body instead [3].

Protein Content of Larva

The chemical analysis points out that the BSF larvae is rich in protein and fat that are both economically viable for livestock feed [3][21]. The result of the protein content measurement is presented in Table 1.

Table 1. Protein content of BSF larva

Larvae age (days)	9	12	16	23	30
Protein content (%)	34.2	36.4	29.9	30.3	32.7

According to Table 1, the protein content of the larvae is approximately 29.9-36.4%. The highest protein level can be found in the 12-day old larva. Meanwhile, the lowest protein level was identified in the 16-days old larva, which enters the pre-pupa stage. During the pre-pupa phase, the larvae stops ingesting. Hence it starts to use the restored nutrition of its body. Restored protein of larvae could approximately reach 40% [13]. The protein level could change if it is fed with a different type of feeding. Insect meal such as BSF larvae can be a valuable component of layer diets, in this experiment, protein source from BSF larvae replaced 50-100% protein from soybean cake [22]. Protein from BSF larvae already used for livestock, poultry, and aquaculture feed. Insects as feed and food have great promise as a new agricultural sector [23]. Protein from BSF Larvae from fifth and sixth instar is 35-38% and contain fatty acid methyl ester (FAME) 33% and 25% respectively [21]. Prepupa stage contains a higher amount of crude fat content (25.2-26.1%) [24].

Decomposition Rate by BSF Larva

During the decomposing process, both of the input and output flow were involved. Input is an inflow of material into the decomposition process, and the output is the outflow [25]. The rate of decomposition that was measured based on the percentage of reduced mass from the whole sample is presented in Figure 5.

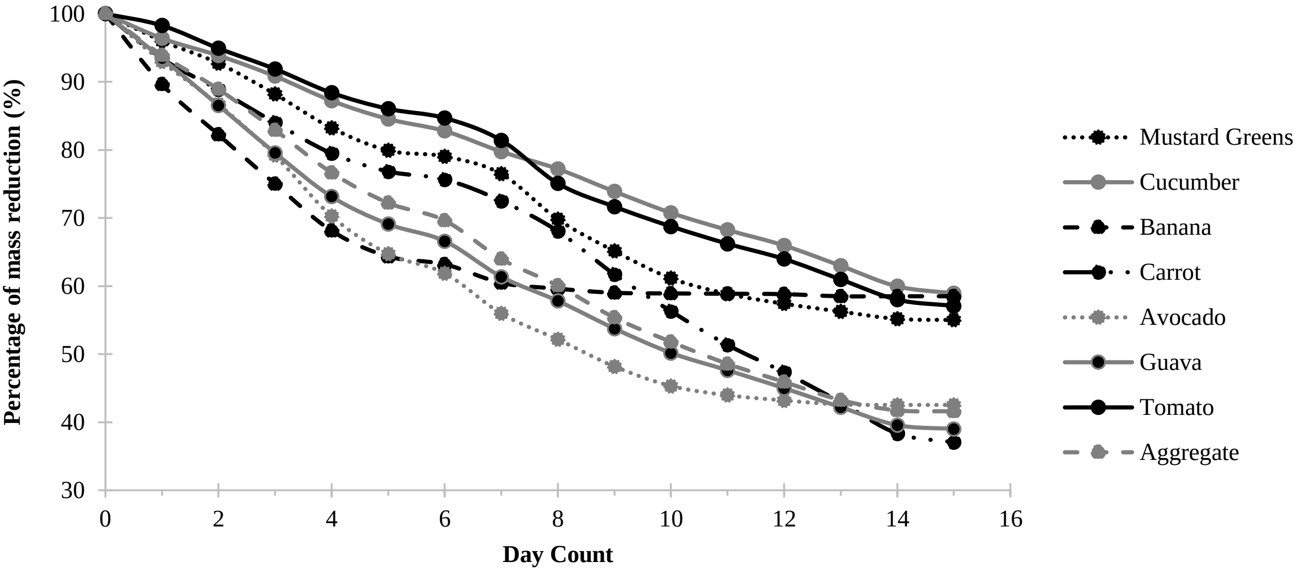

Figure 5. Percent of mass waste reduction

Each sample of waste has its different percentage of waste reduction that is determined by the larva's ability to consuming waste. Considering the experiment result that is presented in Figure 5, the most effective waste reduction occurred in the carrot waste.

Decomposition Characteristic of Organic Waste by BSF Larvae

The identification of the reduction percentage, WRI, DMCR, ECD, and survival rate is presented in Table 2. The highest reduction percentage and WRI can be founded in the carrot sampled. The highest FMCR was identified in banana waste, while the highest DMCR can be found in aggregate waste. The aggregate waste is also the one with the highest ECD. Among all samples, the ones with the highest survival rate are the waste of banana and avocado. Based on the household scale experiment that has been undergone in 15 days, the obtained WRI is approximately 83%, while the DMCR is 40 mg/larva/day. In this case, the WRI and DMCR are higher as compared to the laboratory scale experiment due to the usage of leachate that infiltrates into the water directly. Thus the waste decomposition is more effective.

Table 2. Reduction percentage, WRI, DMCR, ECD, and survival rate

Parameter	Sample types							
	MG	Cu	Ba	Ca	Av	Gu	To	Ag
Reduction (%)	45	41	42	63	57	61	43	58
WRI (%/day)	3.0	2.7	2.8	4.2	3.8	4.1	2.9	3.9
FMCR (mg/larva/day)	26	24	67	30	53	54	21	50
% DMR	88	89	53	85	38	49	74	88
DMCR (mg/larva/day)	23	21	37	26	20	26	15	44
ECD (%)	9	8	5	6	5	3	10	11
Survival Rat*e* (%)	36	15	100	53	100	48	41	37

Note: MG = mustard green; Cu = cucumber; Bn = banana; Ca = carrot; Av = avocado; Gu = Guava; To = tomato; Ag = aggregate

Performance Test of Organic Waste Decomposition Result

The decomposition result is also compared with the national standard, namely SNI 19-7030-2004 [26]. The experiment result is presented in Table 3.

Table 3. Analysis result of decomposed material based on SNI 19-7030-2004

Parameter	Unit	Standard	Decomposition period	
			15 days	30 days
Temperature	C	Groundwater temperature	27.8	28.2
Colour	-	Black	Black	Black
Nitrogen (N)	%	>0.4	1.8	3.6
Carbon (C)	%	9.8-32	14.6	27.6
P_2O_5	%	>0.1	1.43	0.14
C/N	-	10-20	8	8
K_2O	%	>0.22	5.44	7.88
Cobalt (Co)	Ppm	<34	7.9	0.9
Zinc (Zn)	Ppm	<500	150	132
Calcium (Ca)	%	<25.5	4.6	4.2
Magnesium (Mg)	%	<0.6	0.5	0.2
Iron (Fe)	%	<2.0	2.1	1.0
Manganese (Mn)	%	<0.1	0.22	0.02

Based on the result of sample analysis as presented in Table 3, in 15 days, the C/N ratio parameter, Manganese (Mn) and Iron (Fe) did not comply with the standard. However, the result of 30 days decomposition shows a better result, even though the C/N ratio parameter did not meet the standard.

CONCLUSION

The conclusion that can be drawn from the research are as follows:

1. The percentage of organic waste reduction by BSF larvae is approximately 41-63%. The obtained FMCR is 21-67 mg/larva/day, and the ECF ranged from 2.60-11.18%. The identified survival rate is 15-100%. In terms of mass, the most significant one is identified in the aggregate waste sample, in which the transformation reached 4.5 gr/20 individuals. To sum up, the best sample decomposition process by the BSF larvae is in the aggregate form.
2. The highest protein content of the BSF, i.e. 36.39%, can be obtained from the 12 days old larva.
3. The compost quality resulted from 30 days decomposition process of organic waste from the traditional market meets the standard of the compost quality as regulated in SNI 19-7030-2004, except the C/N ratio parameter.

SUGGESTION

Based on this research, the author would like to suggest several points for the next research as follows:

1. Indonesia should have a formal research procedure on the decomposition of organic waste by utilizing the BSF larva
2. Extensive research on decomposing tub should be conducted to investigate the most conducive setting for the breeding of the BSF larva.
3. The design of the conversion process from solid organic waste into protein needs to be studied in detail.

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