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Analysis of Organic Waste Decomposition and Quality of Organic Fertilizer Using Earth Worms and Black Soldier Fly (BSF)

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ABSTRACT

Organic waste for organic fertilizer is needed to increase soil fertility. This study aims to analyses the organic waste decomposition and the quality of organic fertilizer using earth worms and Black Soldier Fly (BSF) produced by Anyar Sari Market. The research used was a simple randomized block design with 9 treatments, namely P0, P1, P3, P4, P5, P6, P7, and P8 which repeated 3 times. Samples that have been weighted were put into the place of manufacture of organic fertilizer mixed evenly with cow manure and chicken manure according to the treatment. Earthworms and BSF larvae were stocked according to treatment after the media was 14 days old with 50% humidity. The parameters were the characteristics of organic fertilizers, levels of odor and structure of organic fertilizers, water content of organic fertilizers, percentage of weathering, and pH of organic fertilizers. The treatments had significant effect on observed parameters. The decomposition rate of P4 treatment increased by 67.66% compared to P0 which was only 27.67%. The suggestion was to use earthworms and BSF larvae by to accelerate the decomposition of the organic waste and to improve the quality of organic fertilizer.

1. INTRODUCTION

Waste problem is a phenomenon that occurs in all major cities in Indonesia. The waste problem occurs because of the large amount of waste production. Population growth, changes in consumption patterns, and people's lifestyles increase the quality and quantity of waste generation, types, and diversity of waste characteristics [1, 2].

Denpasar City, as the capital of Bali Province and a tourism center, is also experiencing problems in managing waste generation [3-5]. Waste management in Denpasar City can be done by separating organic and non-organic waste. Organic waste can be reprocessed into a useful form. The generation of organic waste in Denpasar City is often found in traditional markets. One of the biggest market in Denpasar City is Anyar Sari Market which is located in Ubung Kaja Village, North Denpasar District. Anyar Sari is one of the largest traditional markets that provides vegetable and fruit commodities, produces a lot of organic waste from fruit and vegetable waste. Anyar Sari market waste processing efforts that have been carried out were collection, compaction/compacting and burning. The disadvantages of this activity where it requires large land, strategic position, requires complex tools, takes a long time, low income, requires experts, has a limited distribution of market reach and has the risk of air pollution. Utilization of organic fertilizer systems can be used to change the expensive and unsustainable waste processing at Anyar Sari market.

Utilization of organic fertilizer has been widely applied to support agricultural needs [6-11]. Organic waste in the form of leaves, crop residues, and straw were often used as material for making compost. A safe composting process and accurate treatment can prevent plants from disease or blight which can be seen from the decomposition process of organic matter that has taken place perfectly as seen from the brown-black color to the color of the soil, the C/N ratio is 10-30, the temperature is approximately the same as ambient temperature and the compost is odorless [12, 13].

The handling solution offered for safe composting process was based on decomposition of organic waste by utilizing the presence of decomposing organisms. In this case, the decomposing organisms were earthworms *(L. Rubellus*) and Black Soldier Fly (BSF) larvae. The selection of earthworms and BSF was based on their ability to consume organic waste at a high speed and have the ability to adapt to various environmental conditions and will remain in place as long as food is still available.

The BSF fly has attracted a lot of interest from researchers because of its ability to break down organic waste, especially when combined with animal manure. BSF larvae can very quickly convert fresh organic matter into compost and biomass rich in protein and fat. BSF adults can live independently and do not require special food or maintenance treatment. Adult flies or larva do not bite, are not harmful to human health, and are not vectors of pathogens.

This study aims to determine the effect of earthworms and Black Soldier Fly (BSF) on the rate of weathering of organic waste and the quality of organic fertilizer produced by Anyar Sari Market. Organic fertilizer was obtained by mixing organic waste and chicken and cow manure. Through decomposition of organic waste by utilizing decomposing organisms, it produced organic fertilizer at low and sustainable costs so it is beneficial for farmers.

Previous research entitled vermicomposting process of mixed food waste and black soldier fly larvae composting residue by using *Eudrilus eugeniae* which aimed to determine the degradation level of BSF larvae composting residue mixed with food waste and to analyze the quality of the vermicompost produced resulted the highest degradation rate was observed when applying the composition of the substrate 1:2 with 15 g worms/kg substrate. The reduction rate was 59.92% and vermicompost production was 75.47%. The best quality of vermicompost was achieved in the same composition but with 20 g worms/kg substrate [14].

Other research entitled chemical characteristics of Bio-Vermigot (vermicompost and kasgot) fertilizer with the combination of Black Soldier Fly larvae and earthworms by using cow manure and banana stem using Factorial Randomized Block Design to produce a combination of vermicompost and kasgot (bio-vermigot) with earthworms and BSF larvae. The combination of decomposer agents that can produce bio-vermigot with the best Phosphorus content is 25% earthworms were BSF larvae 75% with banana stem waste, Potassium and C/N ratio in all treatments not eligible with national standards [15]. Meanwhile this research using organic waste from vegetables and fruits to analyses the variety of organic waste decomposition and the quality of organic fertilizer using earth worms and Black Soldier Fly (BSF). Earthworms and BSF are decomposers in the composting process which can speed up the decomposition process of organic waste into smaller particles and produce nutrients for the soil. Earthworms and BSF are an alternative in solving the problem of organic waste and useful for the soil.

2. METHODOLOGY

2.1 Research location

This research was conducted in Ubung Kaja Village, North Denpasar District, Denpasar City, Bali Province. Denpasar City is the capital city of Bali Province, Indonesia. Beside its administrative function, Denpasar City is also the heart of tourism, education, economy, trade and services in Bali Province [16]. Figure 1 shows map of the research location.

2.2 Materials and tools

The materials of this research are cow manure, chicken manure, organic waste from the Anyar Sari market, earthworms and Black Soldier Fly (BSF) larvae. Other ingredients are chemicals for laboratory analysis, namely catalysts/ mixtures (potassium sulfate, copper sulfate and metallic selenium), salicylic acid, concentrated sulfuric acid, 85% concentrated phosphoric acid, 40% NaOH solution, and 0.1 N mixed indicator (bromkesol) green and red metal, boric acid solution, HCl, 4% NaF solution 0.025 N.

The research equipment consisted of laboratory equipment, namely, a digestion apparatus, a distillation apparatus, a Kjeldahl semi-micro flask, a Kjeldahl semi-micro heater, a burette, a pipette and a PH meter. The equipment used in the field were buckets, scales, shovels or hoes, thermometers, knives or machetes, gloves and masks.

2.3 Methodology

This research began by taking samples of organic waste in Anyar Sari Market, Denpasar City. Samples were taken randomly at 10 locations. The waste was vegetable and fruit waste. The waste was stirred evenly and cut into pieces of approximately 2 cm then to stir again so that it was completely evenly distributed. The organic waste then went through 9 treatments and 3 replications as follows:

1. P0=3 kg Organic Waste
2. P1=2 kg organic Waste + 1 kg cow manure + 20 g BSF larvae
3. P2=2 kg Organic Waste + 1 kg Cow manure + 40 g BSF Larvae
4. P3=2 kg Organic Waste + 1 kg Cow manure + 500 g Earthworms
5. P4=2 kg Organic Waste + 1 kg Cow manure + 750 g Earthworms
6. P5=2 kg Organic Waste + 1 kg Chicken Manure + 20 g BSF Larvae
7. P6=2 kg Organic Waste + 1 kg Chicken Manure + 40 g BSF Larvae
8. P7=2 kg Organic Waste + Chicken manure 1 kg + 500 g Earthworms
9. P8=2 kg Organic Waste + 1 kg Chicken manure + 750 g Earthworms

Figure 1. Map of the research location

After 14 days, earthworms and BSF were added according to the treatment. Each treatment was kept at 50% humidity and the structure remained crumbly by stirring evenly every 3 days so that the decomposition process went well. The parameters observed in this study were changes in color, odor, structure of organic fertilizer, percentage of water content, decomposed organic matter and pH of organic fertilizer. Observation of organic fertilizer parameters was carried out during weeks I, II, III, IV and V after stocking of earthworms and BSF.

The color of the organic material observed visually refers to the appearance of the organic material. The smell of organic matter was observed directly by using respondents. The structure of the organic matter observed directly refers to the lowness of the organic matter. Determination of the water content of organic fertilizers was carried out at the end of the composting process. By weighing 10 grams of organic fertilizer samples and then in the oven for 24 hours then cooled in a desiccator and weighed. Water content (%) is determined based on Eq. (1).

$$Water\ content\ (\%) = \frac{\text{initial weight (kg)} - \text{dry weight(kg)}}{\text{initial weight (kg)}} \times 100\% \qquad (1)$$

Decomposition of organic matter from organic fertilizers was determined using a sieve at the end of the composting process. The organic fertilizer was sieved through a 2.5 mm sieve by comparing the percentage of the initial weight with the weight of the material that passed the sieve. The organic matter decomposition formula (%) is determined according to Eq. (2).

$$\text{Decomposition (\%)} = \frac{\text{weight of materials after sieve (kg)}}{\text{initial weight (kg)}} \times 100\% \qquad (2)$$

Determination of the pH of organic fertilizers was carried out at the end of the composting process by weighing 10 grams of organic fertilizer samples, then by 25 ml addition of distilled water and then shake for 25 minutes. After letting it sit for 5 minutes then measured using a pH meter. Figure 2 shows the research flow chart.

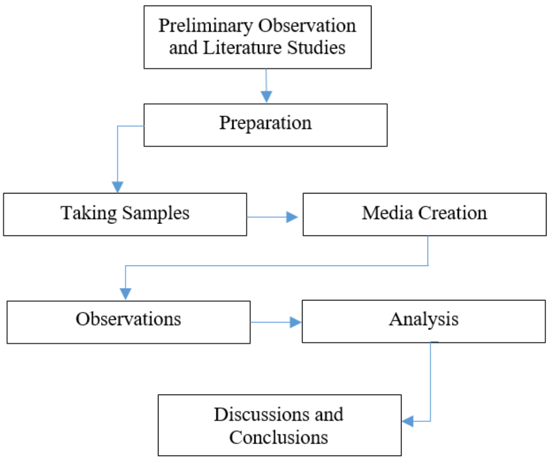

Figure 2. The research flow chart

3. RESULT AND DISCUSSIONS

3.1 Result

During the decomposition process, there is a change in the color of the organic fertilizer to brown. At week 4 and 5, the color of the fertilizer showed the characteristics of optimal maturity, which was blackish brown. After the second week of the decomposition process there was a change in the density of the organic fertilizer into coarse crumbs. In the third week the density of organic fertilizer material becomes loose, slightly coarse, at the fourth week it was still slightly loose, and in the fifth week it was finely loose. The finely loose density of organic fertilizer was found in both the treatment with cow manure and chicken manure. Treatment of earthworms weighing 500g and 750g gave very high decomposition ability with aerobic process, while treatment of BSF the organic fertilizer was still watery but with anaerobic process.

The treatment of P3, P4, P7 and P8 shows that in the second week the color changes and the third week the color of the organic fertilizer has begun to ripen, there is no difference between cow manure and chicken manure as well as the weight of earthworms. It is different from BSF because what is included is that the larvae need time to hatch so that the second week has not shown a color change after the fifth week, it just shows the maturity of organic fertilizer for BSF larvae of 20g and for BSF larvae weight of 40g the 4th week has shown maturity. Table 1 shows the different color of the organic fertilizer. Table 2 shows density changes in organic fertilizer. Figure 3 shows the color differences of the organic fertilizer during the decomposition processes.

The observations on the odor of earthworms in organic waste which mixed with cow manure and chicken manure shows that from week 1 an odor begins to form. While the second week there is no smell, this happens because earthworms can release biofilm gas that can eliminate odors and release antibiotics through the fluids that come out of their bodies. Table 3 shows the different odors of the organic fertilizer.

The results of the decomposition rate test presented in Figure 3 show that the P0 treatment (control) has the lowest average percentage of decomposition, which is 27.17%. The highest percentage of decomposition was found in treatment P4 of 94.33% followed by P8 (92.75%) and P3 87.61%. Figure 4 shows the results of the decomposition rate.

Table 1. Color change in organic fertilizer

Week	Replication	Treatment								
		P0	P1	P2	P3	P4	P5	P6	P7	P8
1	I	1	1	1	1	1	1	1	1	1
	II	1	1	1	1	1	1	1	1	1
	III	1	1	1	1	1	1	1	1	1
2	I	1	1	1	2	2	1	1	1	1
	II	1	2	2	2	2	1	2	2	2
	III	1	2	2	2	2	1	2	2	2
3	I	1	2	2	3	3	2	2	3	3
	II	1	2	2	3	3	2	2	3	3
	III	1	2	2	3	3	2	2	3	3
4	I	2	2	3	3	3	2	2	3	3
	II	2	2	3	3	3	2	3	3	3
	III	2	2	3	3	3	2	3	3	3
5	I	2	3	3	3	3	2	3	3	3
	II	2	3	3	3	3	2	3	3	3
	III	2	3	3	3	3	3	3	3	3

Annotation: 1=slightly light black and brown; 2=black slightly yellow and brown; 3=brownish black

Table 2. Changes in density of organic fertilizer

Week	Replication	Treatment								
		P0	P1	P2	P3	P4	P5	P6	P7	P8
1	I	1	1	1	1	1	1	1	1	1
	II	1	1	1	1	1	1	1	1	1
	III	1	1	1	1	1	1	1	1	1
2	I	2	2	2	2	2	2	2	2	2
	II	2	2	2	2	2	2	2	2	2
	III	2	2	2	2	2	2	2	2	2
3	I	2	2	3	4	4	3	3	4	4
	II	2	2	2	4	4	3	3	3	4
	III	2	2	2	3	4	2	3	4	4
4	I	2	3	3	4	4	3	3	4	4
	II	2	3	3	4	4	3	3	4	4
	III	2	2	3	4	4	3	3	4	4
5	I	2	4	4	4	4	3	3	4	4
	II	2	4	4	4	4	3	4	4	4
	III	2	3	4	4	4	3	3	4	4

Annotation: 1=dense/tight, 2=coarse crumbs, 3=loose slightly coarse, 4=loose and smooth

Table 3. Odor changes in organic fertilizer

Week	Replication	Treatment								
		P0	P1	P2	P3	P4	P5	P6	P7	P8
1	I	2	2	2	2	2	2	2	2	2
	II	2	2	2	2	2	2	2	2	2
	III	2	2	2	2	2	2	2	2	2
2	I	2	1	1	3	3	1	1	3	3
	II	1	1	1	3	3	1	1	3	3
	III	1	1	1	3	3	1	1	3	3
3	I	2	1	1	3	3	1	1	3	3
	II	1	1	1	3	3	1	1	3	3
	III	1	1	1	3	3	1	3	3	3
4	I	1	1	1	3	3	2	2	3	3
	II	1	2	2	3	3	2	1	3	3
	III	1	1	1	3	3	1	3	3	3
5	I	2	2	2	3	3	2	3	3	3
	II	2	2	2	3	3	2	2	3	3
	III	2	2	2	3	3	2	3	3	3

Annotation: 1=Very Odor, 2=Smelly, 3=Neutral

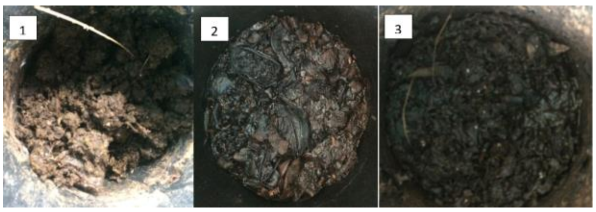

Figure 3. Different color of the organic fertilizer; (1) Slightly light black and brown, (2) Black slightly yellow, and (3) Brown and brownish black

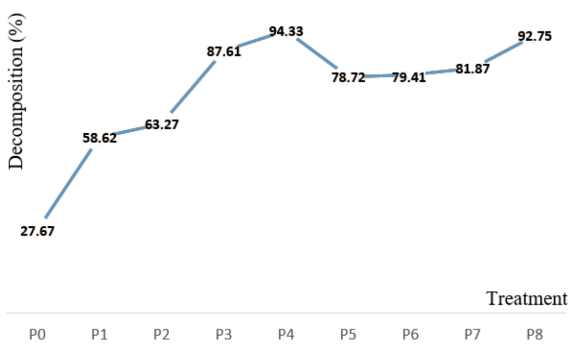

Figure 4. The results of the decomposition rate of organic fertilizer

Figure 4 shows that in treatment P4 which consists of 2 kg organic waste + 1 kg cow manure + 750 g earthworms has similar effect to treatment P8 which consists of 2 kg organic waste + 1 kg chicken manure + 750 g earthworms and treatment P3 which consists of 2 kg organic waste + 1 kg cow manure + 500 g earthworms. This shows the importance of earthworms in decomposition processes.

The result of water content, pH and organic matter presented in Figure 5. The result shows that the P4 treatment (cow manure and earthworms) the lowest water content is 22.17%, while the highest water content is in P0 treatment, which is 32.81%. The decomposition of organic matter is obtained in the fifth week, where the highest percentage occurred in treatment P4 of 94.33 % which compared to P0 of 27.67% or an increase of 66.66%. The increase in the percentage of organic fertilizer decomposition was followed by a decrease in the water content and an increase in the pH of the organic fertilizer as shown in Figure 4. The lowest water content in P4 treatment was 22.17% compared to P0 at 32.81% or a decrease in water content was 10.64%. The highest degree of acidity (pH) in P4 and P8 treatments was 8.05 and 8.08, respectively, or an increase of 27% compared to P0 with a pH of 6.35. This difference in water content is caused by the different composition of organic materials used to make organic fertilizers and decomposers, namely earthworms and BSF larvae.

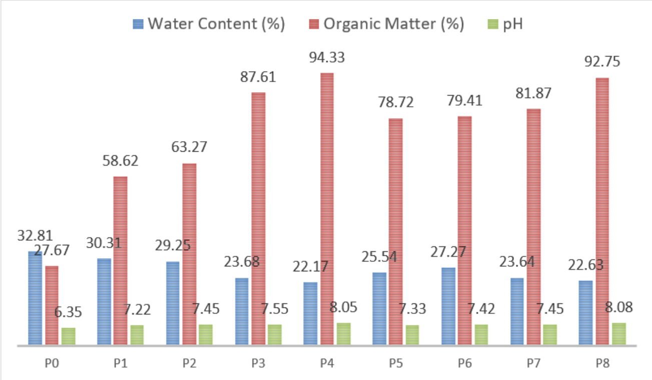

Figure 5. Water content, organic matter and PH of organic fertilizer (%)

The decomposition process began after the mixed organic waste were cut approximately 2 cm. The addition of earthworms and BSF larvae accelerated the decomposition process within 14 days. The treatment to organic fertilizers significantly affected the pH of organic fertilizer. Only treatment P0 with pH of 6.35 was significantly different from treatment P1 to treatment P8 with approximate pH of slightly acidic to slightly alkaline, namely 7.22 to 8.08. Organisms were active at neutral to slightly acidic pH, namely at pH 5.5 – 8. The role of earthworms and BSF in improving the quality of organic fertilizers is that BSF can eat organic waste that is still fresh and hasn't been fermented, while earthworms can eat organic waste after decomposition. After undergoing decomposition for 5 weeks, it was very clear that the difference in the quality of organic fertilizer was seen from the smell, structure, water content, percentage (%) degraded and from pH as seen in Table 4.

Table 4. Quality of organic fertilizer due to decomposition from earthworms and BSF after 5 weeks

Type of Macro organism	Quality of organic fertilizer after 5 weeks					
	Color	Odor	Structure	Water content (%)	% degraded	pH
Earth worm	Brownish black	Neutral	Loose and smooth	22.17	92.75	8.08
BSF	Brownish black	Odor	Loose and smooth	27.27	79.41	7.45

3.2 Discussions

Changes in the color of organic fertilizer from light brownish black to yellowish black and brownish black to brownish black occurred from the second week and continued until the 5th week, due to the process of decomposition by earthworms and BSF.

The activity of microorganisms along with the activity of earthworms and BSF caused a change in the particle size of the organic waste to be smaller which was followed by a darker color change. The brownish black color occurs as a result of the media being mixed with earthworm excrement and also BSF feces. Changes in the color of organic fertilizers were clearly visible after being compared with media without earthworms and BSF until week 5.

Table 1 shows that at week 5 both the earthworms and BSF compost were ripe with blackish brown color, odorless with loose and smooth texture. This is a characteristic that this compost has decomposed properly so it has available nutrients to increase nutrients in the soil.

The change in the density of organic matter from solid to loose and fine is strongly influenced by the carbon-to-nitrogen (C/N) ratio. The higher the C/N ratio, the harder the structure. While organic waste mixed with cow manure or chicken manure has a decreased C/N ratio that causes a loose and smooth structure. Earthworms also play a role in lowering the C/N ratio of organic matter by digesting and decomposing plant remains that have died and converted into humus and natural nutrients [17].

The C/N ratio also act as a parameter that is related to the catalyst of decomposition of organic matter, indicating the availability of nitrogen in a soil. Both C and N status associated with C/N ratio play a key role in regulating soil organic matter mineralization. The ratio of C/N indicates the rate of decomposition of organic matter and this results in the mineralization of soil. In general, Carbon (C) and nitrogen (N) in soils are the main component of organic content which effect the soil fertility [18, 19].

The decomposition process creates the formation of organic acids. This acidic condition triggered the growth of fungi that help decompose lignin and cellulose compounds in organic matter [20-22]. During the decomposition process, the organic acids will become neutral and the pH of the organic fertilizer after the ripening process usually ranges from 6-8, black colored, odorless, crumbly textured and ripe with a Carbon to Nitrogen ratio < 20 [23-25].

Earthworms and BSF affect the water content, C-organic and pH of soil. Earthworms are able to break down mineral particles into smaller units so that the distribution and cycle of C-organic stays longer in the soil. Earthworms increase water content by mixing and aerating the soil to help water infiltrates to the soil. Earthworms helping moderate alkaline soil pH by adding organic matter, bringing up minerals in the soil, and feeding the microbes which make nutrients more available to plant roots. While the treatment of BSF has a lower C-organic content, pH and water content because BSF only uses organic matter as food so it is useful for the composting process but does not produce as much nutrients as earthworms [26, 27].

The digestive tract of earthworms contains a consortium of synergistic organisms such as protozoa, bacteria and micro fungi that are able to degrade cellulose compounds and contain various enzymes such as lipase, protease, urease, cellulase, amylase and chitins [28, 29]. The urease enzyme is an enzyme that plays an important role as a catalyst for the hydrolysis of urea into ammonia and carbamic acid [30].

Based on the results of the study, it can be suggested that to accelerate the decomposition of organic waste and to improve the quality of organic fertilizers, earthworms and BSF larvae can be used by mixing them in organic waste with cow manure or chicken manure.

4. CONCLUSIONS

The treatment of earthworms, organic waste, and cow manure had a significant effect on the characteristics of organic fertilizer (color, odor, and structure of organic fertilizer), water content of organic fertilizer (%) and pH of organic fertilizer as well as the percentage of organic matter decomposed in treatment P4 (addition of 1 kg cow manure and earthworms 750 g) of 94.33%, an increase of 66.66% compared to P0 (control) of 27.67%. Earthworms and BSF larvae can be used to accelerate the decomposition of organic waste and to improve the quality of organic fertilizers by mixing them in organic waste with cow manure or chicken manure.

In the P4 treatment, the color was brownish black due to the media mixed with earthworm and BSF excrements. The odors become neutral faster because of the role of earthworms, which are symbiotic with various types of microorganisms and the role of calciferous glands on earthworms that secrete calcium, which plays a role in controlling pH to keep it neutral. Organic fertilizers also loosen faster due to the influence of the carbon to nitrogen ratio which causes a loose and fine structure. Water content, organic C and pH of organic fertilizers were influenced by the type of organic fertilizer and degrading agent of earthworms and BSF. Cow manure and chicken manure are lower in organic C content as well as their pH and water content due to the activity of earthworm and BSF.

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