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Regional Case Study

Tanjung Perak Port Solid Waste Composting using Black Soldier Fly Method

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Abstract
One of the supporting facilities for operational activities at the Tanjung Perak Port is the existence of adequate green open spaces. The type of plant that is widely planted is the Angsana tree. Since 2018, this port has had an innovation to reuse waste from trimming activities to become compost, but the results are not optimal because there is still a lot of compost in the form of whole leaves. In this research, the composting method will be tested using Black Soldier Fly larvae and local microorganisms from banana hump. Compost material in the form of the waste of Angsana leaves is mixed with the waste of mackerel fish which comes from processing activities of mackerel fish food. Variations were made with different feeding regimes for Black Soldier Fly larvae, namely 3 weekly, daily, and weekly with dose of local microorganism banana hump as much as 15 mL/kg. The results of composting showed that the variations of feeding regime have significant effect for compost quality.

Keywords: Compost; angsana leaf; mackerel fish waste; black soldier fly larvae

1. Introduction

Tanjung Perak port in Surabaya already conducted waste treatment using composter unit for converting yard waste, Angsana (Pterocarpus indicus) leaf from open green space to compost. Composter has been installed in port facility using windrow composting without any activator. Unfortunately, the compost resulted was still in the form of intact leaves. It can be cause by characteristics of the Angsana leaf have low Nitrogen (Ghaisani, 2014).

Biodegradation of organic waste comprises many technologies such as anaerobic digestion, vermicomposting, composting, anaerobic digestion. Anaerobic digestion needs particular control condition which are not easy use for large scale. Vermicomposting needs to consider various environment condition affecting worm's activity and resulting low bioconversion rate. Composting was potential treatment technology for converting biodegradable waste into more valuable products such as energy, soil amendment or fertilizer and protein for animal feed (Lohri et al., 2017). It is an exciting global technology to recycle waste into resources following with various considerations such as nature of waste, cost and environment impact of resulting compost to soil (Azim et al., 2017). Composting is favorable method for treating biodegradable waste using specific microbes (Shoobhany et al., 2018; Guidoni et al., 2018).

In the past decade, specific technology using Black Soldier Fly (BSF), Hemertia Illucens has attracted great interest can process various of biodegradable waste up to 80% and compost food waste in short period (Lalander et al., 2020; Surendra et al., 2020). BSF has reported as an effective method of biowaste conversion to decompose organic waste with degradation efficiency of its ranges from 55-80% (Mertenat at al., 2019; Beesigamukama et al., 2021; Kaya et al., 2021). BSF offers not only solution for waste management but also provide protein source has potential to support increasing global demand of animal feed (Mertenat et al., 2019).

Optimal environment condition needed to achieve the best condition for survival, growth and breeding of larvae. pH value is one of the parameters that affects life cycle and survival of BSF. Initial pH for organic waste biotransformation around 6.0 to 8.0. Moisture was an essential role in composting BSF with varies between 65% and 90% (Liu et al., 2021). Feeding regime of BSF larvae composting influence the process performance of bioconversion. Lump sum feeding on BSF composting resulting unfavorable on growth of larvae and process efficiency (Lopez et al., 2020). Feeding frequencies affected the performance of bioconversion reactors to process waste utilize both microorganism and microorganism (Silva et al., 2021).

In order to accelerate composting process, need to involve activator added to feedstock. Activator could be resulted from local microorganism (MoL) such as banana hump. Microorganisms produced from banana hump as bio-activator be able to produce compost between 10 – 20 days with recommended high C/N ratio (Wardani, 2018). Based on laboratory analysis, Angsana leaf contain 18.21% of C; 0.55% of N ; 66.2% of moisture; 33.11 of C/N. Refer to this characteristics, for processing Angsana leaf into compost, needed other feed stock with high Nitrogen such as mackerel fish waste. Fishermen in East Java catch a lot of fish from the Scombridae family, which includes mackerel, tuna, etc. (Statistics of Surabaya City, 2021). The potential for fish waste produced is in line with the size of the fish catch. Recently, the mackerel fish waste produced from marketplace and food processing has not been treated to meet legal requirement about solid waste management. Based on previous research on mackerel fish waste, the C/N value of fish waste was 4.9 with details of C-organic content of 45.98% and total nitrogen of 9.39% (Illera-Vives, et al, 2013). The potential for fish waste to be composted is large enough so that it can be combined with Angsana leaves to obtain good quality compost.

The aim of the study is to examine the impact of feeding regimes on BSF composting to digest mackerel fish and yard waste in order to improve the existing composter in Tanjung Perak port. The research was conducted in three scenarios (R); the first, the feeding provided every three weeks (R1); the second, the feeding occurs every day (R2); and the third is based on every weeks (R3). In this study, we explore the role of BSF in converting waste to compost. The research also sought to provide advice and knowledge on how the composting facility can best operate using appropriate scenario to fulfill compost quality standard.

2. Methodology

2.1. Measurement of the Content of C, N and Water Content in the Compost Material

The amount of each material that has been composted can be determined based on the C/N ratio of each material. The C/N ratio is one of the factors that affect the composting process (Mortier et al, 2016). The levels of C and N and the ratio of C/N have been presented in **Table 1.**

Table 1. Characteristics of each compost material

No.	Compost material	C-organic (%)	Nitrogen (%)	C/N ratio	Moisture content (%)
1.	Fish mackerel waste (FMW)	21.38	4.16	5.14	48.91
2.	Angsana Leaves (AL)	18.21	0.55	33.11	66.2

2.2. Determination of the Compost Composition

The compost material in this study that has been composted was AL and FMW. Based on the results of the calculation formula that has been carried out, it was obtained that the composition of the compost material consists of 71% of AL and 29% of FMW. The following was the formula that has been used.

$$\text{C/N ratio} = \frac{C\,(1\,kg\,FMW) + x\,C\,(1\,kg\,AL)}{N\,(1\,kg\,FMW) + x\,N\,(1\,kg\,AL)} \quad (1)$$

Determination of the required mass of BSF larvae can be determined through the following formula (Dortmans et al, 2017):

$$M_{larvero} = L_{larvero} \times M_{total}/L_{total} \quad (2)$$

Where $M_{larvero}$ (gram) is mass of larvae required in the reactor; $L_{larvero}$ (tail) is number of larvae required in the reactor; M_{total} (gram) is mass total of larvae in the box; and L_{total} (tail) is number total of larvae in the box. Thus, the number of BSF larvae that have been used is 1500 fish (50 grams) per reactor. The larvae that have been used are in the form of a trapezoidal prism measuring (30|60) cm x 30 cm x 30 cm.

2.3. Mol Production of Banana Hump

The activator that has been used in this research was MoL of Banana Hump of 15 ml/kg of compost material. The making of MoL of Banana Hump that has been carried out by Karyono et al (2017). The first step is to prepare the ingredients for making the MoL. The ingredients needed are 1 kg of banana hump that has been sliced and mashed to speed up the decomposition process by microorganisms, 0.25 kg of brown sugar as an additional food source for microorganisms, and 2 liters of rice washing water (source of microorganisms). The next step is to dissolve brown sugar with rice washing water into a 5 liter container. After that, add the banana hump that has been smooth into the solution mixture and stir until evenly distributed. The last step is to wait for the fermentation process until 15 days.

2.4. Calculation of Giving Compost Material to Larvae

In this study, giving compost material to larvae was carried out with 3 types of methods, namely 31 weeks, every day, and every week. The amount of compost that has been given to each reactor is 200 mg/larva/day for 21 days of the composting process. In this research, there have been 3 reactors consisting of different times of giving compost material (can be seen in **Table 2.**).

Table 2. Research variable

Giving material compost methods	The making of MoL of Banana Hump as 15 mL/kg[b]	Compost material (mg/material compost/larvae)[*b]
3 weeks	R1	4200
Every day[a]	R2	200
Every week[a]	R3	1400

*compost material mass = feed rate x timing of give compost material
[a]Nyakeri et al., 2019 [b]Karyono et al., 2017

2.5. Composting Reactor

The calculation of the volume of compost needs has been started by measuring the density of the mixture of compost materials. The measurement of the density of the compost material has been carried out with reference to SNI 19-3964-1994. The density of the compost material is calculated using the equation:

$$Density\ (kg/m^3) = \frac{solid\ waste\ mass\ (kg)}{solid\ waste\ volume\ \ (m^3)} \qquad (3)$$

So it has been obtained that the density of the mixed material of Angsana leaves and mackerel fish waste is 202,318 kg/m3 and the required reactor volume is 31.12 liters. The dimensions of the composting reactor have been obtained that: (30|62) cm x 30 cm x 30 cm is a trapezoidal prism (can be seen at **Figure 1.**). The reactor has been closed using a paranet to maintain air circulation and prevent impurities from entering the reactor (Lopes et al, 2020). The reactor design has been given an incline with a slope of 28^o and a pipe is provided at the end for migration when the larvae have reached the prepupa stage (Diener et al, 2011).

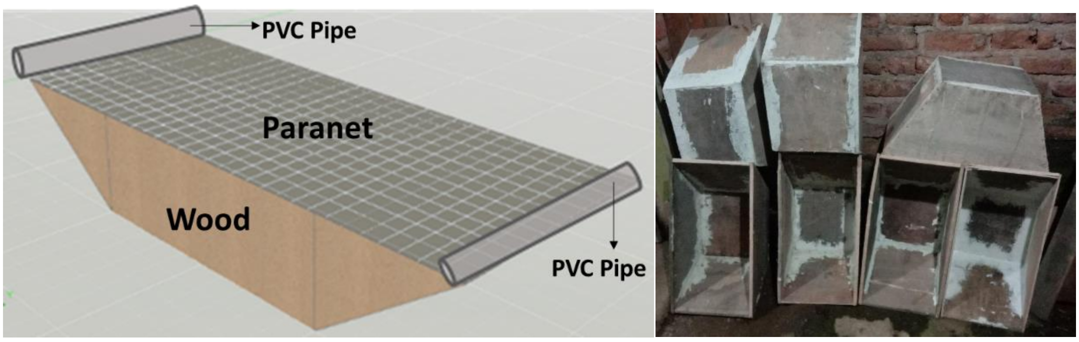

Figure 1. Composting reactor

2.6. Composting Process

The compost material has been mashed and mixed evenly and placed in the research reactor. After that, the compost material has been given 15 mL of banana weevil MoLe/kg of compost material. Then 1500 larvae (50 grams) per reactor were added to the reactor. The provision of compost material has been adjusted to the method (can be seen in Table 2.). During the composting, measurement of pH, temperature and moisture content compost done every day while measurement of C/N ratio compost done at begin and final composting process. Levels of pH, temperature, and moisture content was monitored daily for 21 days. pH using digital soil pH meter, temperature using digital soil thermometer, moisture content using digital soil humidity meter. It is important for material to be in the form of a slurry to make it easier for the larvae to eat. To make compost material in the form of a slurry, the compost material needs to be pulverized using a blender. Epstein (2017) explained that becauses the size of the compost material are quite small, it cause the decomposition process by bacteria much faster.

2.7. Compost Characteristic Analysis

1) Analysis of compost characteristics consisting of temperature, moisture content, pH, C/N ratio, phosphorus, and potassium has been compared with the Indonesian National Standard SNI 19-7030-2004. Measurements of temperature, water content, pH have been carried out every day of composting and measurements of the C/N ratio, phosphorus, and potassium have been carried out at the end of composting,
2) Biomass characteristics of BSF (waste shrinkage index, feed conversion efficiency, substrate shrinkage, larval growth rate) (Jucker et al, 2020).
   BSF larvae from each reactor were taken every 3 days for weighing. Meanwhile, to determine WRI and ECD, we have weighed the amount of compost material given, the remaining substrate from the composting activity, and also the biomass value of BSF larvae. The determination of each of these values can be calculated using the following equation:

$$WRI = \frac{\frac{(W-R)}{W}}{d} \times 100 \quad (4)$$	$$ECD = \frac{B}{W-R} \quad (5)$$
$$SR = \left(W - \frac{R}{W}\right) \times 100 \quad (6)$$	$$GR = \frac{L_1 - L_0}{d} \quad (7)$$

Where WRI is *waste reduction index* and W(gram) is number of feeds given; R is residual composting substrate (grams); d is duration of composting (days); ECD is Efficiency of Conversion of the Digested food; B is larvae biomass total (gram); SR is *substrate reduction* (%); GR is *larvae growth rate* (gram/day) was determined by larvae mass ending (L_1) minus Larvae mass early (L_0) dividing duration of composting (days).

3) Analysis of The Effect of Giving Compost at Different Times has been carried out using the Multivariate Analysis of Variances (MANOVA) method using the SPSS 26 and Minitab 19 programs.

3. Result and Discussion

3.1. pH Levels

Figure 2. shows the pH level during the research process. The results show that the pH levels of compost are stable at neutral value of 7, except for the first 5 days where the pH levels was significantly decrease to a strong acidic value (4.5-5.0). The decrease in the pH value of compost can be associated with microbial activity which decomposes compost material and forms organic acids (Setyorini et al., 2013). But then, the value of the pH will slowly go to the neutral value because of the mineralization process and the formation of ammonia from nitrogen which will increase the pH value of the compost (Karyono et al., 2017). According to Indonesia National Standard (2004) with final pH value of 7, indicates that the composting results are acceptable to be used. pH is 6 – 7.5 which shows that microorganisms can decompose waste optimally (Anindita, 2012). pH of composting in all reactors almost same.

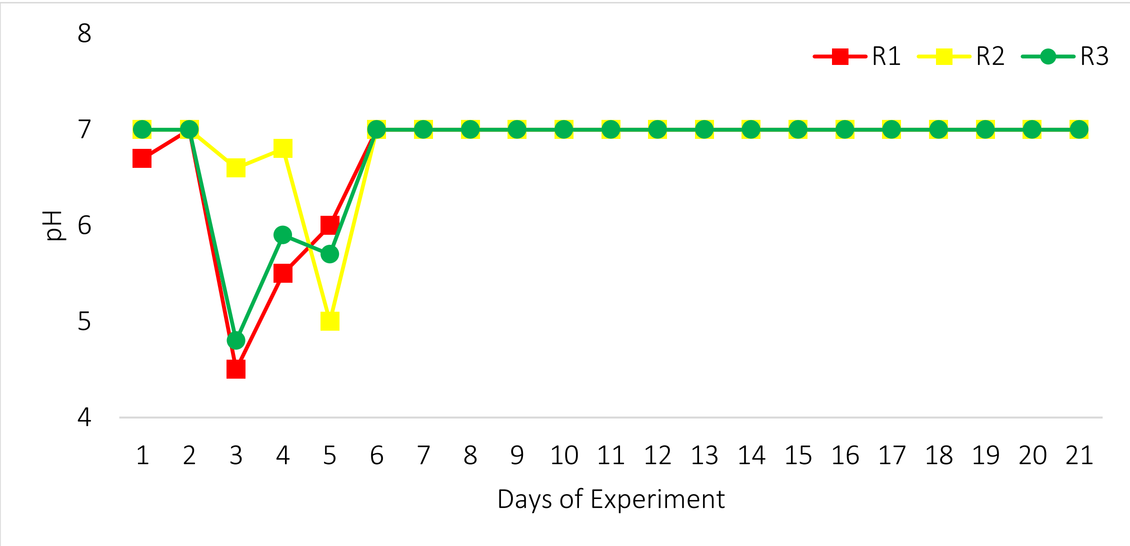

Figure 2. pH levels

3.2. Temperature

The second parameter that are monitored daily are temperature levels (Can be seen at F**igure 3.**). In this study, the average composting temperature of the reactors R1, R2, and R3 ranged from 23-52.7 °C, while the optimal temperature for BSF larvae was 30-40 °C (Dortmans et al., 2017). This is due to the activity of microorganisms in the compost that produces heat. The initial temperature of the material at R1, R2, and R3 is quite high 40-45 °C, because the characteristics of the waste of mackerel fish and goose leaf can produce high heat. Therefore, it is necessary to turn the compost material for 7 days at the beginning of composting to release the heat trapped at the bottom of the compost to be replaced with cooler material at the top (Setyorini et al., 2013). On day 1-16 The results of the temperature analysis for each reactor R1, R2, and R3 fluctuated and increased significantly on day 10. The increase in temperature indicates the decomposition process of compost material will run faster (Suwatanti and Widiyaningrum, 2017). The composting success indicator can be monitored from the composting temperature. Abi et al. (2020) explained that temperature is closely related to the composting phase, which includes 3 stages; the lag phase, the active phase, and the maturation phase of the caring phase. The lag phase occurs as soon as the composting conditions are set and the microbes adapt to grow. The active phase is a transitional phase from the lag phase which is characterized by an increase in the number of microbes and microbial activity in the waste so that the temperature of the compost material will increase. The maturation of the caring phase occurs after all the biodegradable organic matter has been decomposed. On the 17^{th} to the 21^{st} day, the temperature decreased to room temperature with the respective values of the reactors R1 (23°C), R2 (22°C), and R3 (24°C). According to the Indonesian National Standard (2004) with a final temperature value of 22-24°C, it indicates that the compost has matured.

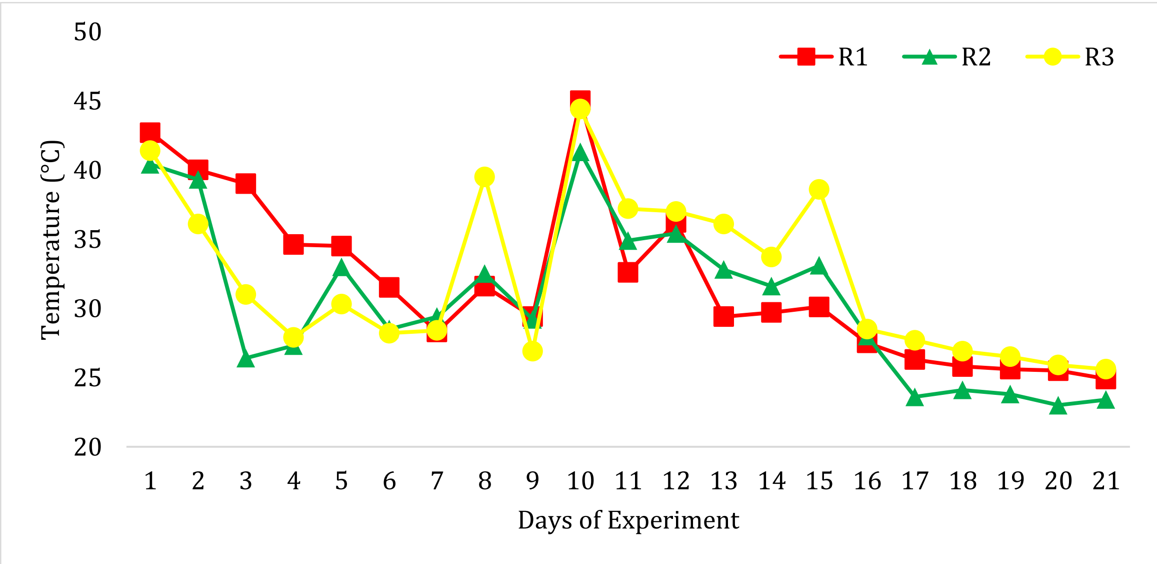

Figure 3. Temperature levels

3.3. Moisture Content

The last parameter that is monitored every day is the water content of the compost (can be seen in **Figure 4.**). Daily monitoring of water content in compost is related to the survival of BSF larvae. In the study of Dortmans (2015), it was stated that BSF larvae live optimally in materials with a water content range of 70 – 80 %. In this study, the average water content of the compost at R1, R2, and R3 on the first week of composting showed fluctuations from 40 – 90 %. This is because at the beginning of the composting process, the moisture content of the compost material decreases as the water content of the compost material decreases to the bottom. Then the compost material is turned over, which causes the water at the bottom of the compost to be evenly mixed throughout the compost and the compost moisture content to rise (can be seen at **Figure 4.** on day 2 and day 5). Microorganisms use water as the transport of organic substances and nutrients, to ensure that organic matter can be decomposed by microorganisms (Arum, 2019). Excess water will result in reduced air volume, but on the contrary if it is too dry the decomposition process will stop. The wetter the pile, the more often it must be turned over to maintain and prevent the proliferation of anaerobic bacteria (Lopes et al., 2020). **Figure 4.** shows that on day 10 to day 21 the water content of the compost for R1, R2, and R3 is in the range 65 – 90 % which indicates the water content in the compost is already in the growth range for BSF larvae to develop. optimal for degrading organic matter.

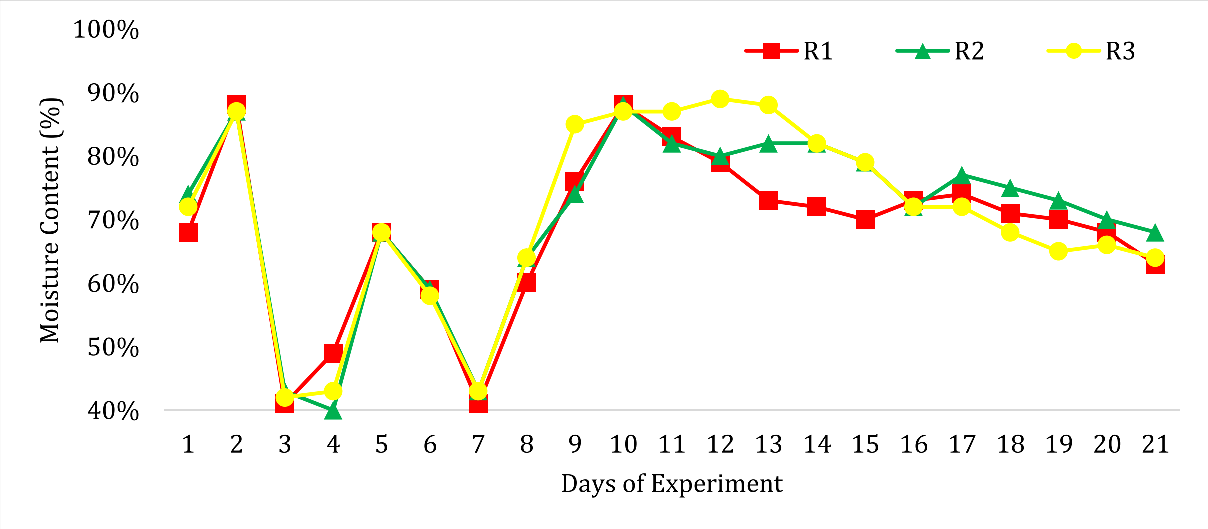

Figure 4. Moisture content levels

3.4. C/N Ratio

The value of the C/N ratio is directly related to the activity of microorganisms that require carbon as energy and cell building, as well as nitrogen for protein synthesis and forming cell growth (Budiarta, 2017). In the composting process, compost material that has a high C/N ratio needs to be mixed with compost material that has a low C/N ratio (Illera-Vives et al., 2015). Therefore, in this study, Angsana leaves with a high C/N ratio were mixed with mackerel fish waste which had a much lower C/N ratio. The requirement for the C/N ratio of compost according to SNI 19-7030-2004 is in the range of 10-20. The results of the research in **Figure 5**. show that the reactors R1, R2, and R3 have C/N quality that meet the SNI compost standard. The C/N value of reactor R1 (C/N = 12) was the highest compared to R2 (C/N = 11.3) and R3 (C/N = 10.4). This is because in R1 the addition of compost material is carried out only 1 time at the beginning, namely by directly adding 4200 mg of compost material. BSF larvae decompose organic matter more quickly when organic matter is given at the beginning so that the C/N value of the R1 reactor is higher than the others. During the decomposition process, carbon organic matter is consumed as an energy source by microorganisms by releasing CO_2 and H_2O for aerobic processes. The carbon concentration continues to decrease, while the nitrogen content increases due to the decomposition process of compost material by microorganisms that produce ammonia and nitrogen (Gani et al., 2021). Most of the organic content in the material will decompose during the composting process. Microbes take energy for the decomposition of organic matter from calories produced in biochemical reactions, such as the continuous conversion of carbohydrates into CO_2 and H_2O gases (Busato et al., 2018). On the other hand, nitrogen is needed by microorganisms to maintain and form body cells. With sufficient nitrogen content, organic matter will be easily decomposed, because decomposing microorganisms need nitrogen for their development (Aditya et al., 2015). In addition, the compost material in the reactor can lose nitrogen from the compost pile during the composting process caused by gas emissions in the form of NH_3 (Astuti et al., 2014).

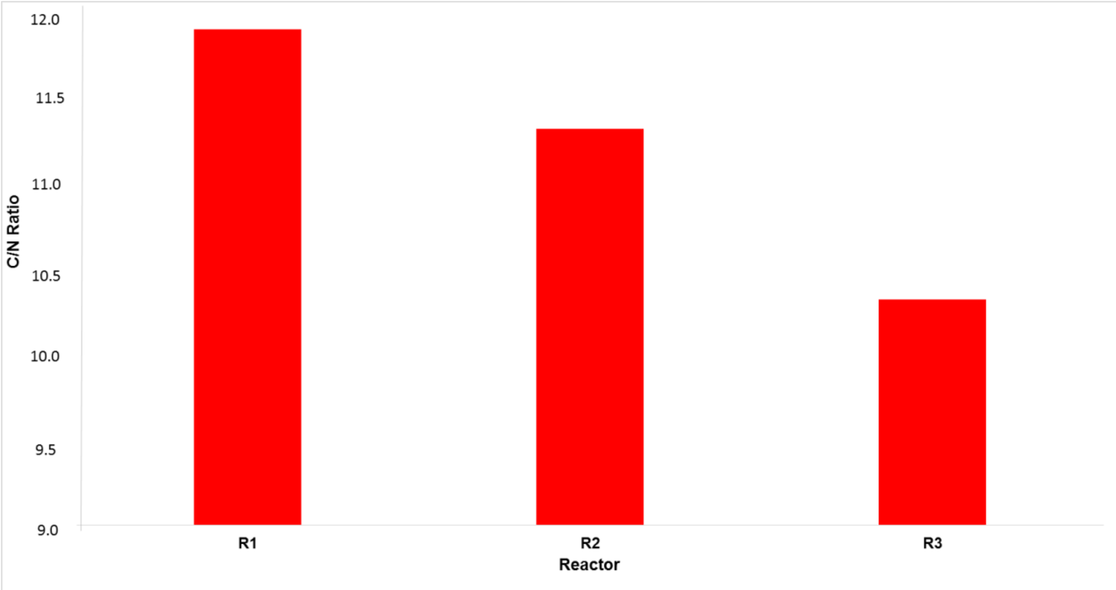

Figure 5. C/N ratio value

3.5. Waste Reduction Index

Waste Reduction Index shows the amount of reduction of composting materials that occurs during the composting period. The WRI value was obtained by comparing the substrate shrinkage value with the composting duration. The WRI value during the composting period (can be seen at **Figure 6.**) from day 2 to day 21 was highest WRI value was in the reactor with daily feeding R2 ($WRI_{average}$ = 6.7), followed by weekly feeding R3 ($WRI_{average}$ = 4.1) and the lowest WRI value was 3-week basis feeding R1 ($WRI_{average}$ = 2). Previous research conducted by Nyakeri et al. (2019), stated that the highest feed shrinkage value is in the reactor with daily feeding, with the lowest value is the reactor with lump sum feeding or only given once at the beginning of composting. This can be caused by the small amount of feed given to the reactor daily, causing micro-organisms and larvae can easily decompose the waste. While in the 3-week reactor, the amount of feed given was very large at the beginning of the composting, so the decomposition process was slower than reactor with daily and weekly feeding (Nana et al., 2018).

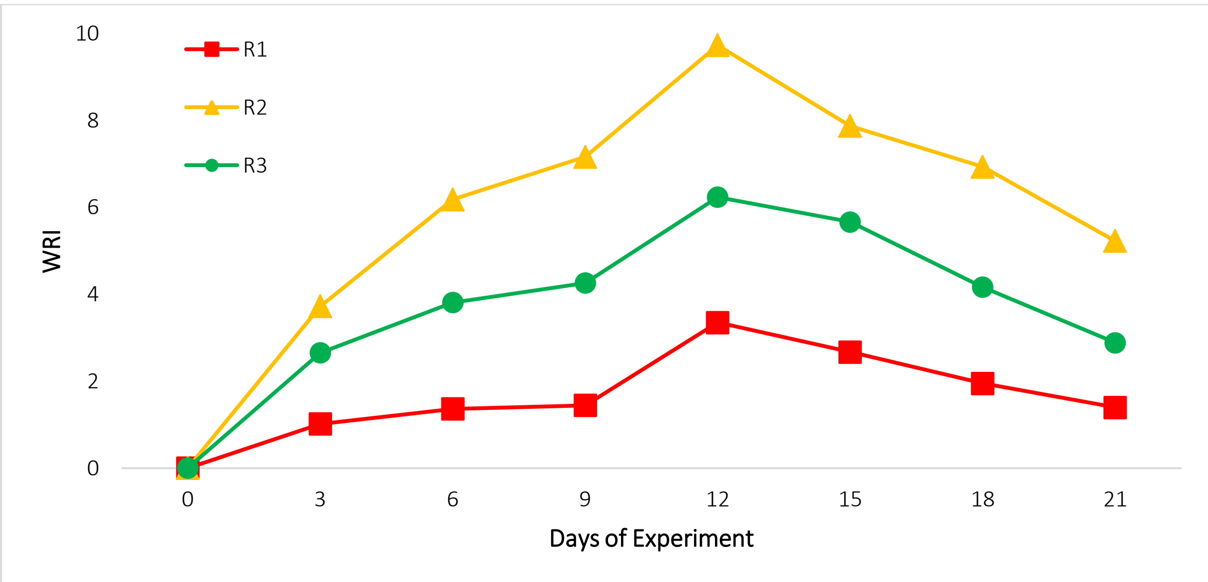

Figure 6. Waste reduction index

3.6. Statistical Analysis

Statistical analysis was conducted to examine does differences in feeding regime gave a significant effect on dependent variables. The test results are as follows in **Table 3**.

Table 3. Statistical analysis results

Variables	Normality Test		Homogenity Test		Analysis of Variances	
	Method	P-Values	Method	P-Value	Method	P-Values
pH Levels	Ryan-Joiner	>0.100	Levene	0.998	One-way MANOVA	0.007
Temperature	Ryan-Joiner	>0.100	Levene	0.996	One-way MANOVA	0.009
Moisture Content	Ryan-Joiner	0.075	Levene	0.992	One-way MANOVA	0.006
C/N Ratio	Ryan-Joiner	0.057	Levene	0.958	One-way MANOVA	0.007
Waste Reduction Index	Ryan-Joiner	>0.100	Levene	0.989	One-way MANOVA	0.001

Normality and homogenity test were conducted as an assumption for the One-way MANOVA test. Data needs to be normally distributed and the two population variances are equal. With $\alpha = 0.05$, none of the data violate the assumption of normality and homogeneity of variance. Analysis of variance were performed on the pH levels, temperature, moisture content, C/N ratio, and waste reduction index as shown in **Tables 3**. The effects of feeding regime was significant to all of dependent variables, with significant value of 0.001 – 0.009.

The value of the C/N ratio is directly related to activity microorganisms that require carbon as energy and cell building, and nitrogen for protein synthesis and form cell growth (Budiarta et al, 2016). This can affect the composting process, the compost material have a high C/N ratio need to be mixed with compost material that has a Low C/N ratio (Illera-Vives, 2015). In the study, there were various additions of different compost materials at R1, R2, and R3 so that they affected the C/N ratio, pH, air content and temperature. Microorganisms use water as a transport substance and nutrients organic matter, so that in the presence of air the The organic matter can be broken down by microorganisms (Ratna et al, 2017). because the difference in the amount of compost material in each reactor affects the air content. In addition, in reactors with the addition of different amounts of compost material, the pile of compost material is not too high so that there is a difference in heat temperature in the compost material, it is easier to off (Abid, 2020). the addition of this compost material affects the speed the process of mineralization and the formation of ammonia from materials nitrogen which will increase the pH value of the compost (Karyono, 2017).

4. Conclusions

The conclusion in this study is the difference in feeding regime has a significant effect on the value of pH, temperature, water content, C/N ratio, and WRI index with a significance value of 0.001 – 0.009. The three variations feeding regime have met the compost quality standard according to SNI with the best variation being R1 (feeding regime every 3 weeks). Further research can analyze the effect of variations in the dose of banana hump for compost quality.

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