Study of organic market waste processing using continuous flow bin vermicomposting meet several nutrient parameters

Kasam¹, F M Iresha¹, T B Kusuma¹, R Umam², A Mutolib³ and A Rahmat⁴

¹Department of Environmental Engineering, Islamic University of Indonesia, Indonesia
²Faculty of Science and Technology, Kwansei Gakuin University, Japan
³Postgraduate Program, Siliwangi University, Indonesia
⁴Research Center for Limnology, Indonesian Institute of Sciences, Indonesia

E-mail: fajri.mulya@uii.ac.id

Abstract. The processing of markets' organic wastes in Indonesia, especially in Yogyakarta, is still done conventionally, that most of it, is directly composted at the Landfill or sometimes even directly dumped without going through the composting process. This research was conducted to maximize the processing of the organic waste that was generated by the local market, using continuous flow bin and vermicomposting to make it more economically beneficial to the community and to test the chemical parameters like Carbon / Nitrogen, Phosphor, and Potassium level from the vermicast, which is the after-product of vermicompost process. The research process goes through several stages: the acclimatization stage, the feeding stage or the vermicompost process, and the testing stage. Carbon/Nitrogen ratios, Phosphor, and Potassium values in the final results of the three reactors in the composting process meet the composting criteria according to SNI 19-7030-2004. The Carbon/Nitrogen measured in the three reactors were 10.2%, 16.6%, and 11.54%, respectively. The phosphorus levels (P) available in the three reactors were 0.32%, 0.35%, and 0.33%. Potassium (K) levels available in the three reactors were 0.26%, 0.58%, and 0.67%. The K values in reactors 2 and 3 meet the compost criteria or standards from SNI 19-7030-2004 because it is more than 0.20%, while for reactor 1 it is still below the criteria standard.

1. Introduction

Environmental problems related to the management and processing of market organic waste in Indonesia today are still the concern of many environmental experts. Almost all urban environments produce a high volume of market organic wastes. Although the character of the wastes different in each area, it causes the same problem, like odors, water, air pollution, and also acts as a vector of disease. In contrast to developed countries, like in Indonesia, the waste problems in developing countries are much more complicated because, in addition to cost factors, it is also related to public awareness of how to treat wastes are still limited.

So far, organic waste produced by the local market is still conventionally processed. Most of it is composted at the Landfill or sometimes even directly dumped. Only a few regions have successfully processed their waste, resulted in the reduction of the volume of waste that ends up in the Landfill. Waste management classified into a hierarchy that consists of 6 steps: reduce, reuse, recycle, treatment, dispose, and remediate [1]. In this research, market organic waste will be processed using a worm reactor with the continuous flow bin method with the hope of implementing this process in the waste management hierarchy.
Organic wastes have a characteristic that easy to rot, high methane content, and high organic content. Because of this, in most cases, organic wastes were processed into biogas [2]. If these compounds are not handled properly, they will cause a comprehensive negative impact on the environment. For example, if organic waste is only left in open spaces, the methane content will evaporate and combine with the air, and if the volume is high enough, it will become greenhouse gases that will cause global warming.

In terms of management and processing, Indonesia still needs a lot to improve. If we look at the surrounding conditions, we can easily find organic wastes everywhere, more so in traditional markets, pieces of vegetables or fruits can be seen scattered all around. Besides, not only with poor management, most of the organic waste processing in Indonesia still uses conventional methods, like composting with a bio starter (EM4). This conventional method of composting is considered not to be able to solve the problem of organic waste due to the long period of composting time, around 2-3 months or more.

The purpose of using the vermicompost reactor with the continuous flow bin model is that it is considered very suitable for social, economic, and cultural conditions. In this study, nutrient content such as Carbon, Nitrogen, Phosphor, Potassium will be analyzed and compared to the Indonesian National Standard for Compost (SNI 19-703092004).

2. Methods
The research was conducted at the Integrated Laboratory of Environmental Engineering, Islamic University of Indonesia Yogyakarta, and market organic waste was taken from the Pakem market, Sleman district, Yogyakarta. The vermicompost reactor is located in a different location due to considering biological factors that must be considered the worm's life cycle. The time of the research was between July – September 2018.

The vermicomposting process was carried out using the macroorganism Lumbricus rubellus worm, grown in a continuous flow bin reactor. The research process goes through several stages: the acclimatization stage, the feeding or vermicomposting process, and the compost testing.

In the acclimatization stage, the worms are put into the reactor that cow manure has already been laid out on its base. The cow manure act as a "bedding" for the worms; this is called vermibed. The worm acclimatization process is carried out for 48 hours [3]. However, on other references, the worm acclimatization process is carried out for 72 hours[4]. In this study, the acclimatization process was carried out within 48 hours. The acclimatization process has failed and must be repeated if 100% of the worm population dies or leaves the site.

At the vermicomposting stage, the reactor used is a "continuous flow bin" with Lumbricus rubellus worms, and 3 different treatments were applied. The 3 different treatments are feeding ratio with bedding 1.25: 7 at the first reactor (R1), 1.5: 7 at the second (R2), and a 1.75: 7 ratio at the third (R3). From the three reactors, the weight of the wastes was weighted from the start and end of the process and every 3 days because the feeding process is done every 3 days because the decomposition process of market organic waste lasts for 3 days.

Market organic waste is taken using buckets, and plastic bags referring to SNI 19-3964-1994 then weighed using a portable digital scale. The process of taking organic waste at Pakem Market is done randomly. Even though it is done randomly, compostable organic material is separated from those that are not suitable for compost in the feeding process. Market organic waste suitable for compost includes all kinds of green vegetables, tomatoes, and fruits. Meanwhile, organic waste that is not suitable for compost includes rotten meat, bones, onion skins, and fruit skins with sharp surfaces such as durian skin. In this research, the required waste varied, 1.25 , 1.5 kg and 1.75 kg every 3 days.

The vermicomposting process is stopped when the suitability of the compost criteria is met. This criterion was based on SNI 19-7030-2004 regarding compost maturity standards. At the composting stage, the increase in worms weight also weighted every 3 days using a digital balance or digital scale, and this is because the feeding process ends on the 3 days, evidenced by the exhaustion of the organic waste biomass consumed by worms.

After the vermicomposting process is complete, the resulting vermicast is tested. Vermicast was tested because it was considered to represent the characteristics of composting results. Because the worms lived in the vermibed, the consumed organic waste was then excreted, left in the vermibed.
Testing on the vermicomposting process focuses on several chemical parameters: C-Orgarnic, Nitrogen, Phosphor, and Potassium, and through this, the C/N ratio can be calculated.

The tools used in this research are
1. Reactor manufacturing
   In the manufacture of vermicompost reactors, tools that were used are saws, stainless steel, bionets, strings of stainless steel composite, PVC, valves, sheet wood / wooden boards. The design can be seen in Figure 1.
2. Vermicompost stage
   In the vermicompost stage, the materials used included 6.5 kg of Lumbricuss rubellus worms, fresh cow manure (4 days old), market organic waste, table salt, and water. While the tools used include portable digital scales, rulers, thermometers, water sprinklers, latex gloves, masks, and transparent plastic.

Figure 1. Vermicompost Reactor Design

In this study, the in-container vermicomposting reactor was used. The in-container composting system is divided into two, bin and batch types. When comparing the two options, the cost and complexity of the bin type are considered to be more suitable with the local culture because it is easy to apply and the cost of making is cheap. In the continuous flow bin type of reactor, the composting process utilizes a simple aeration method; here is a photo of the reactor used.

3. Result and Discussion

3.1. Continuous flow bin reactor
The vermicompost process can use 2 main methods, namely an open vermicompost system and container vermicompost [5]. In this study, the in-container vermicomposting reactor was used. The container composting system is divided into two bin and batch types. In this research, the bin type was used because it is cheaper and easier to apply in developing countries. In terms of cost and level of complexity, the bin type is considered more suitable to the local community's culture because it is easy to apply and cheap to manufacture. A continuous flow bin is composting with the aeration method.

In developed countries, especially those with intensive waste processing, the continuous flow bin uses mechanical aeration with the help of a blower at the bottom of the container. This research is focused on the vermicompost process and the final composting results and does not discuss reactor planning and construction. In this study, the composting process was carried out ex-situ, the market organic waste was taken from the local market, Pakem traditional market, located in Sleman Regency,
Yogyakarta, and then brought to the processing plant. Meanwhile, the in-situ type is a vermicomposting process that is composted by applying or installing a reactor at the traditional market.

The continuous flow bin reactor is the most profitable worm reactor when applied for commercial purposes [6]. There are several factors that make a continuous flow reactor to be chosen commercially, among others, because it is cheap, easy to maintain because vermicast can be harvested easily, and worms rarely / never leave the reactor.

3.2. Acclimatization stage
The acclimatization process is the initial stage that determines whether worms can be used as decomposition agents or not. The vermicompost process in this research used a type of *Lumbricus rubellus* worm, while the vermibed used was fresh cow manure (4 days). In this study, various worm biomass of 1 kg, 1.5 kg, and 2 kg was used to decompose the waste of 1.25 kg, 1.5 kg and 1.5 kg which was given once every 3 days. The conditions experienced by Gajalakshmi, and. Abassi [7], showed that worms have a high mortality rate when the density is too high, this is due to an anaerobic process in the vermibed layer, resulting in the worms being deprived of oxygen. The conditions that occur in this study can be seen in Table 1.

| Researcher          | Worms’ biomass (gram) | Mass Reduction Efficiency (gram) | Time (days) |
|---------------------|-----------------------|----------------------------------|-------------|
| Edwards et al. [5]  | 900                   | 1500                             | 7           |
| Fadilah et al. [8]  | 93.4                  | 1307.6                           | 10          |
| Rahmatullah et al. [3] | 250                 | 1000                             | 7           |
| Experimental        | 2000                  | 1750                             | 3           |

Table 1 explained that there is a comparison between several literature. Comparisons were made on the basis that the three researchers used the same kind of worm, namely *Lumbricus rubellus*. In addition, the vermibed used is the same, namely cow manure. For the feeding stages, the three researchers used the same composition of organic waste, namely vegetables (heterogeneous) and fruit (mixed) even though the percentage composition was different.

3.3. Feeding stage
The composition of organic waste used in this research are rotten tomatoes and vegetable waste because they mostly dominate the waste compositions [9]. The feeding process begins by giving treatment to each reactor. Reactor 1 was given a treatment of 1.25 kg of market organic waste every 3 days. Reactor 2 was given 1.5 kg of organic waste every 3 days. Meanwhile, reactor 3 was given 1.75 kg of market organic waste every 3 days. While the increase in worm biomass weight is normal, but the speed of organic waste reduction in the reactors, were observed to be faster than some previous studies. Apart from the high worm density, the reactor also supports the high rate of vermicomposting process due to the aeration holes on both sides of the reactor and also because of their pre-treatment so that the worms can decompose the organic waste at increased rate. This shows a great potential if it is to be applied to a larger project scale where the reduction of market organic waste at the source will certainly be greater.

The vermicompost process carried out by the author can be categorized as good because the temperature in the reactor is very stable, there are no flies around the reactor, and there is no leachate. For the trend of increasing worm biomass in each reactor can be seen in Figures 2.
3.4. Vermicast testing

Vermicast or often called vermicompost is defined as the end result of the vermicomposting process, vermicast contain high levels of nutrients that can be used for fertilization and plant fertilization [5]. Several criteria for vermicast maturity level are very varied, but because the author is in Indonesia, it refers to SNI 19-7030-2004 regarding physical and chemical criteria for compost maturity. The following are the results of vermicompost carried out by researchers compared to the standard criteria from SNI 19-7030-2004 (see Table 2).

Table 2. Observation of chemical characteristics of vermicast

| No. | Parameters | Unit | Min | Maxi | Initial Data | Reactor 1 | Reactor 2 | Reactor 3 |
|-----|------------|------|-----|------|--------------|-----------|-----------|-----------|
| 1   | Odor       |      |     |      | Smell of soil| Smell bad of fresh cowdung | Smell of soil | Smell of soil | Smell of soil |
| 2   | Temperature| °C   |     |      | Temp. of Groundwater | 34°C | 21°C | 23°C | 23°C |
| 3   | Color      |      | Black as Soil |     | Green Tea (matcha) | Black as Soil | Black as Soil | Black as Soil | Black as Soil |
| 4   | C/N        | %    | 10  | 20   | 26.3 | 10.2* | 16.6* | 11.54* |
| 5   | P (P₂O₅)  | %    | 0.1 |      | 0.16 | 0.32* | 0.35* | 0.33* |
| 6   | K (K₂O)   | %    | 0.2 |      | 0.43 | 0.26* | 0.58* | 0.67* |

*Data that fulfill the SNI 19-7030-2004 Standard

The chemical elements measured above are compost standards that refer to SNI 19-7030-2004, vermicompost is categorized as compost even though worms are used in the process of decomposing organic waste. In conducting the research the writer refers to the SNI mentioned above in order to find out the level of compost maturity, and below is the process of justifying the level of compost maturity.

The physical properties of ripe compost based from the technical guidelines, SNI 19-7030-2004, are black soil and soil odor. It can be seen from the sample photos that both samples 1, 2, and 3 look different in color from the initial data. The initial data in the photo shown cow dung that is 4 days old (still fresh), while samples 1, 2, and 3 are vermicast from reactors 1, 2, and 3 respectively. moss green tends to be brown, while samples 1,2, and 3 are ground black. Apart from color, differences are also clearly visible in the smell and density of cow dung. In the preliminary data, it can be seen that the sample has a dough-like texture, which is smooth, while the vermicast sample, namely 1,2, and 3 have the texture of the soil. In addition, the substrate smells different due to the different methane content.

The initial data is taken from fresh cow dung sample, which is 4 years old, smells very strong compared to samples 1, 2, and 3 which smell like soil. The color and texture of the substrate are closely related to the C/N content because immature compost has a high C/N of more than 20%.
Figure 3. Comparison of Cow Manure after 16 Days of Decomposition by Worms *Lumbricus rubellus*

The level or C/N ratio is an indicator of compost maturity [10]. The vermicompost process is more effective in reducing ammonia levels (the cause of odor in composting process) compared to conventional composting processes because the vermicompost process is able to reduce DOC (Dissolved Organic Carbon) levels [11]. In this study, the C/N content of each reactor was different because in the feeding process various kinds of organic waste were given. Organic waste gives a characteristic on the final vermicast. From the measurement results, it can be seen that the value of C/N is different in each reactor, in principle, the C/N value is known to vary because the given is also different in composition. In this case, when the type of organic waste that was given is dominantly fresh vegetables and fruits, then C-Organic will be higher than organic waste that has withered. Because at the time of acquisition and feeding phase the organic matters were not sorted, the C/N value for each reactor was different. The measured C/N value in the vermicompost process is 14.1% [12].

Apart from C/N, the concentration of other macro elements that are very important are Phosphorus (P2O4) and Potassium (K2O). Phosphorus functions in cell division and fertilization, as well as for the function of flowering and fertilization [13]. The element potassium has several uses in plant metabolism, especially regarding the hardening of stems, roots, and leaves [14]. The following is a comparison of the elemental levels of phosphorus (P) and potassium (K) from the initial data with the vermicast results.
The use of market organic waste as feed has several advantages and disadvantages. The advantages are that the organic matters easy to obtain in large quantity, but the disadvantage is that the quality is not consistent, as a result, the P and K levels of each reactor are not uniform. The P content in each reactor in terms of quality meets good compost standards according to SNI 19-7030-2004 which is greater than 0.1% and the K value also meets the final composting result standard because it is greater than 0.2%. For P and K levels, the authors have not been able to provide comparisons with other researchers because they have not found suitable literature for comparison. However, what needs to be known is that the results of the P content obtained are 0.32 (reactor 1), 0.35 (reactor 2), and 0.33 (reactor 3), the results of vermicast are included in the good compost category because the minimum standard of levels is P according to SNI 19-7030-2004 which is 0.10%. Meanwhile, the K content in reactor 1 was 0.26%, reactor 2 was 0.58%, and reactor 3 was 0.67%. The K values in reactor 2 and 3 meet the compost criteria or standards from SNI 19-7030-2004 because it is more than 0.20%, while for reactor 1 it is still below the compost criteria standard. Things that can affect the quality of compost are nutrition that is given to the worm at the time of feeding because the composition of the substrate given will adhere to the chemical composition of the vermicast.

4. Conclusion

Based on the research conducted that using a continuous flow bin reactor in processing market organic waste based on vermicomposting is considered very relevant and suitable for both socio-cultural and economic conditions. The C/N ratio in the results of the three reactors in the composting process fulfills the composting criteria according to SNI 19-7030-2004. C/N criteria according to SNI must be in the range of 10-20%. The potassium (K) content available in reactor 1 was 0.26%, reactor 2 was 0.58%, and reactor 3 was 0.67%. The phosphor (P) content available in reactor around 0.32-0.35%, which is fulfills SNI 19-7030-2004 standard.

References

[1] Damanhuri E and Padmi T 2010 Pengelolaan Sampah (Bandung-ITB Press)
[2] Wahyuni S 2011 Menghasilkan Biogas dari Aneka Limbah (Jakarta-AgroMedia Pustaka)
[3] Rahmatullah F, Sumarni W and Susatyo E B 2013 Potensi Vermikompos Dalam Meningkatkan Kadar N dan P Pada Limbah IPAL PT. Djarum Indonesian Journal of Chemical Science. 2(2):142-147.
[4] Rahmawati E dan Herumurti W 2016 Vermikompos Sampah Kebun dengan Menggunakan Cacing Tanah Eudrilus eugeneae dan Eisenia fetida Jurnal Teknik ITS. 5(1): 33-37
[5] Edwards C A, Norman Q, Arancon, Rhonda L and Shereman 2011 Vermiculture Technology : Earthworm, Organik Wastes, and Environmental Management (United States-CRC Press Taylor dan Francis Group)
[6] Beetz 2010 Worms for Bait or Waste Processing (Vermicomposting) ATTRA 1-20 www.attra.ncat.org/attra-pub/PDF/vermicomp.pdf
[7] Gajalakshmi S and Abassi S A 2004 Earthworms and Vermicomposting. Indian J. Biotecnol. 3: 486-494.
[8] Fadilah U, Waluyo J dan Subchan W 2017 Efektivitas Cacing Tanah (Lumbricuss rubellus Hoff.) in Degradasi Karbon Organik Sampah Sayur Pasar Tanjung Jember. Berkala Saintek. 5:1-6.
[9] Manuel J, Gómez F, Romero E and Nogales R 2010 Feasibility of vermicomposting for vegetable greenhouse waste recycling Bioresource Technology. 101(24): 9654-9660
[10] Suthar S 2009 Vermicomposting of vegetable-market solid waste using Eisenia fetida: Impact of bulk material on earthworm growth and decomposition rate Ecol. Eng. 35 (5): 914–920.
[11] Nigussie A, Bruun S, de Neergaard A and Kuypera T W 2017 Earthworms Change the Quantity and Composition of Dissolved Organic Carbon and Reduce Greenhouse Gas Emissions during Composting Waste Management Journal. 62: 43-51.
[12] Huang K, Li F, Wei Y, Fu X and Chen X 2014 Effects of Earthworms on Physicochemical Properties and Microbial Profiles during Vermicomposting of Fresh Fruit and Vegetables Wastes. Biores.Tech. 170: 45-52.
[13] Rosmarkam A dan Yuwono N W 2002 Ilmu Kesuburan Tanah (Yogyakarta-Penerbit Kanisius)
[14] Sutedjo M M, Kartasapoetra A G dan Sastroatmodjo S 1996 Mikrobiologi Tanah (Jakarta-Rineka Cipta)