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Fast composting of food waste using thermal composter

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Abstract. Composting is an effective method to treat food waste. If food waste can be reduced from households, the transportation process to landfills can be reduced, cheaper costs, and the amount of waste in landfills. In this study, an innovative composting device-thermal composter was developed to accelerate the composting of food waste at home. This study uses food waste in a mixture of Chinese cabbage *(Brassica rapa subsp. pekinensis)* and rice from a household in Semarang, Indonesia. Food waste was chopped, stirred, heated, and decomposed in a thermal composter. The composting was carried out for three days with moisture content, pH, electrical conductivity, volatile solids, C-Organic, N-Total, P-Total, K-Total, plant growth test (*Vigna radiata*). The results showed that the growth of *Vigna radiata* using compost on the third day was better than on the first day. Final compost quality has water content = 75.16%, pH = 7.09, electrical conductivity = 552 Scm^{-1}, volatile solid = 76.45 %, C-Organic = 7.05%, N-Total= 0.433 %, P-Total= 0.147 mg P_2O_5/100 g, K-Total= 0.149 mg K_2O/100 g. It indicates that food waste can be recycled into useful products on a household scale within three days.

1. Introduction

In Indonesia, food waste is produced as much as 300 kg/person/year and ranks as the second country with the highest food loss and food waste rates in the world in 2019 [1]. All food waste will be disposed to the final processing site through the collection, transportation, and processing at the final processing site (mostly landfill systems). If food loss and food waste can be reduced at home, the transportation process will be more straightforward and cost less.

The household-scale composting system and the community scale system have been carried out by Lu and Sidortsov [2]. By using home-scale composting equipment, residents can compost food waste at home and reduce the volume of domestic waste. Compost products can be used as biofertilizers at home or sold to professional companies. The household-scale composting model provides a reliable alternative solution to the food waste problem. People want food waste to be treated immediately after disposal because it causes leachate and an unpleasant odor.

Apart from these benefits, there are some problems with the household composting model. For example, long composting time, the appliance cannot remove odor emissions during biodegradation [3]. Therefore, an innovative household composting device was developed in this study. The new device consists of a chopper, composting chamber, heater, and spiral stirrer. A thermal composter is a solution that needs further research, and it is simple (it does not require ample space) and a portable unit. Food

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waste is chopped, mixed, heated, and decomposed in a thermal composter, and mature compost can be produced quickly.

Kalamdhad et al. [4] were creating a drum-shaped thermophilic composter with varying temperatures, namely the inlet (60-70°C), middle (50–60°C), and exit (30-38°C). The purpose of the thermophilic composter is to activate microbial metabolism and accelerate the rate of humification of the compost. The composting is also equipped with an aeration process to reduce odors and reduce greenhouse gases [5]. Margaritis et al. [6] found that the physical properties of compost increased due to the increase in porosity of different bulking agents, which allowed better aeration and without moisture. Oktiawan et al. [7] using a bulking agent for mature and stable compost as much as 30% of the total mixture. The size of processed food waste of ±2 mm is more conducive for microbes to carry out metabolism, namely the rate of humification and increased composting efficiency. Odor emissions are inhibited during composting. Awasthi et al. [8] also found that the addition of multifunctional microorganisms resulted in a better germination test with a composting period of 20 days.

The main objective of this study is to evaluate the performance of a thermal composter consisting of a chopping unit, heater, composting unit, and bulking agent. In this study, an innovative composting device-a thermal composter was developed to accelerate the composting of food waste at home. We evaluate the quality of compost based on physical, chemical, and plant growth test parameters.

2. Methodology

The research location is in the Greenhouse of environmental laboratory, Department of Environmental Engineering, Faculty of Engineering, Diponegoro University. The thermal composter has dimensions of length 60 cm, width 30 cm, and height 55 cm. The tool frame is made of stainless steel. The thermal composter consists of an inlet, a food waste grinder (grinder), a spiral stirrer driven by a motor, and a heater. The heater is set at a temperature of ±50°C in order to accelerate microbial metabolism and the rate of humification [3]. The bottom and sides of the reactor are equipped with insulators to reduce the heat that comes out. The schematic of the thermal composter is shown in figure 1.

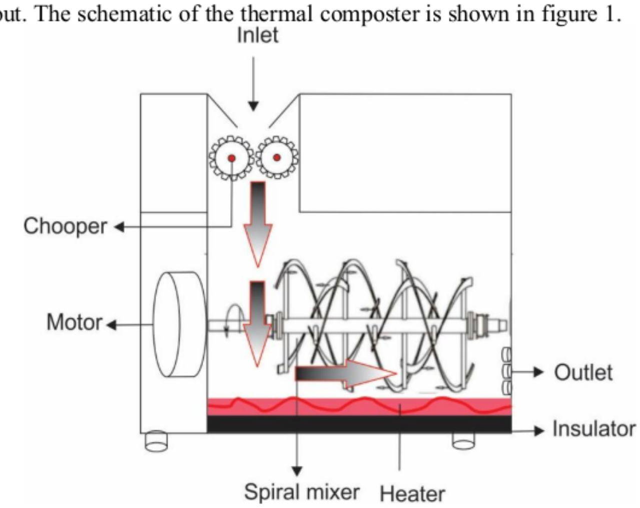

Figure 1. Schematic of thermal composter.

2.1. *Sample preparation*

The main food waste in this study was taken by a household in Semarang, Central Java. Food waste was collected using trash bags, then transported by vehicle to the laboratory of Environmental Engineering, Diponegoro University. Food waste consists of rice waste and fresh Chinese Cabbage *(Brassica rapa*

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subsp. pekinensis). The food waste was mixed to homogenize the sample. The bulking agent comes from mature and stable compost, which is sold in plant stores.

2.2. Experimental setup
A total of 1 kg of food waste was added into the inlet hole and crushed using a chopping unit with a size of ±1 cm. Food waste goes into the composter room. Then the bulking agent was added as much as 30% (v/v) of the total food waste. The mixture was stirred periodically, slowly pushed by a spiral stirrer into the heater chamber, and rotated for 1 minute every 6 hours during the composting. This process is operated using an on/off switch. The temperature in the heater is set at ±50˚C. The composting cycle was carried out for three days by adjusting the rotational speed of the spiral stirrer at 8 rpm. The compost was removed through the outlet. Samples were collected manually from the thermal composter and stored at $4^{o}C$ for further analysis.

2.3. Analysis
Laboratory tests are used to ensure that compost products from food waste are mature and stable. Compost quality is known from the quality (total nitrogen, C-Organic, total P and potassium), water content, and salt. Nitrogen concentration was analyzed using the Kjeldahl method. The C-Organic test used the Walkley-Black method (UV-Vis 150 Spectrophotometer, Thermosciencetific, USA). Potassium test using Atomic Absorption Spectrometer (AAS) (Buck Scientific VGP 210, USA), total P test using spectrophotometric method. The water content test used the gravimetric method by heating the sample at $105^{o}C$ using an oven (Memmert UN 50, Germany).

3. Results and discussion
The composting process is influenced by water content, pH, and the C/N ratio. Table 1 shows the characteristics of food waste and bulking agents. Food waste has a moisture content of 96.06%, higher than the bulking agent water content of 39.49%. The pH value of food waste is 5.11, and the pH of the bulking agent is 5.00. The electrical conductivity (EC) values are 977 Scm^{-1} and 131.9 Scm^{-1}, respectively, for food waste and bulking agents. Parameters of volatile solid food waste are 99.43% and bulking agent 49.05%.

3.1. Changes in pH and EC during composting
The physical and chemical parameters of food waste have changed due to composting. On the first day, the water content of food waste and bulking agents in the composting unit was 61.09%. It has decreased from the previous 96.06%. It is due to the influence of grinding and heating in the thermal composter. The bulking agent functions as a water absorbent [9], while the heating unit assists the evaporation of water. However, the water content increased to 75.16% on the third day. Water contained in food waste undergoes leaching/release from solid material. The process of leachate generation occurs in the hydrolysis stage because the decomposition of organic matter is minimal. As a result, the volume of leachate increases, and the content of organic matter is high[10]. On the other hand, the available bulking agent may have been saturated to absorb water. Leachate from this process is not formed at all, meaning that the ratio of waste and bulking agent of 30% can overcome leachate formation.

In the composting process, the initial pH value was acidic and then increased on the third day. The optimum pH should exist between the range of 7-8 [11]. At the beginning of composting, the pH falls due to the organic acid formation, increasing due to the use of acids and ammonia (NH_3) [12]. Changes also occurred in the EC value, where the initial EC value of food waste was 977 Scm^{-1}. After composting using a thermal composter, it decreased to 552 Scm^{-1}. The EC value is safe for plants when the EC value is below 4000 Scm^{-1}. The EC rejects the salinity of the composting matrix [13]. In this study, the EC value had no impact on biological activity.

3.2. Changes in the concentration of C/N ratio, C-Organic, N-Total, P-Total, and K-Total during composting

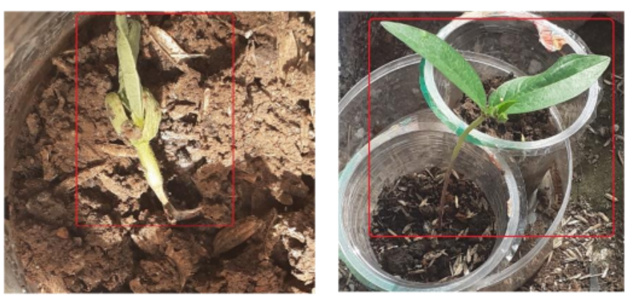
Nutrient concentrations such as C-Organic, N-Total, P-Total, and K-Total need to be analyzed because microorganisms need nutrients for metabolic activity. During composting, microorganisms need a C/N ratio of 30-40 [14]. Changes in nutrient concentration during composting using a thermal composter are shown in table 2. The C/N ratio values in the composting process were 15.4 and 16.3 on the first and third days. Respectively, these values did not meet the standards of the composting process. In this study, the temperature of the compost was in the temperature range of 45.4°C. Higher composting temperatures and microbial agents can help speed up the composting process. The temperature had more effect than the microbial agent because the food waste contained several native microorganisms that could degrade carbohydrates, cellulose, fat, and protein.

Table 1. Initial characteristics of food waste and bulking agent to be processed using a thermal composter.

Parameter	Unit	mustard	Bulking agent
Water content	%	96.06	39.49
pH	-	5.11	5.00
Electrical conductivity	Scm^{-1}	977	131.9
Volatile solid	%	99.43	49.05

3.3. Plant growth test

The difference in the growth of Vigna radiata plants was visible when using compost on the first day (figure 1 (a) and on the third day (figure 1 (b)). During the one-week trial, the number of leaves of Vigna radiata plants used compost on the third day. as much as two. While the roots of the Vigna radiata plant were dry when using compost on the first day. It indicates that the compost on the first day was toxic. Based on the characteristics of the compost in table 2, the pH value of the compost on the first day was 5.29, meaning that the compost was acidic. Plants are not able to grow well when the plant medium is acidic.



(a) (b)

Figure 2. Plant growth *Vigna radiata* when using compost on the first day (a) and compost on the third day (b).

3.4. Compost characteristics after three days of processing

Mature compost must meet specific standards, both physical, chemical, and biological. The characteristics of mature compost produced from a thermal composter were compared with the Minister of Agriculture of the Republic of Indonesia's standard regulation of 70/Permentan/SR.140/10/2011 concerning organic fertilizers, biological fertilizers, and soil enhancers (table 2).

After composting for three days with the addition of bulking agent at an average temperature of 45.4°C, mature compost has a pH of 7.09, EC 552 Scm^{-1}, volatile solid = 76.45%, C-Organic = 7.05%,

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N-Total=0.433 %, P-Total=0.147 mg P_2O_5/100 g, K-Total=0.149 mg K_2O/100 g. The final C/N value indicates that the compost has matured with a C/N value <25.

Cooked compost from food waste has high concentrations of N and P. Therefore, the cooked compost from food waste produced by the thermal composter meets the compost quality standards and is suitable for growing flowers and restoring contaminated soil.

Table 2. Characteristics of compost produced from a thermal composter on the first and third days.

Parameter	Unit	Compost the first day	The third day of compost	Standard*
Water content	%	61.09	75.16	15-25
pH	-	5.29	7.09	4-9
EC	Scm^{-1}	427	552	-
Volatile solid	%	67.21	76.45	-
C-Organic	%	5.84	7.05	Min 15
N-Total	%	0.38	0.433	-
C/N ratio	-	15.4	16.3	15-25
P-Total	mg P_2O_5/100 g	0.25	0.147	-
K-Total	mg K_2O/100 g	0.055	0.149	-

*Standard-based on the regulation of the Minister of Agriculture of the Republic of Indonesia No.70/Permentan/SR.140/10/2011 concerning organic fertilizers, biological fertilizers, and soil enhancers

4. Conclusion

Based on the previous discussion, the main conclusion can be drawn that the growth test of Vigna radiata using compost on the third day is better than the first-day compost. The quality of the compost on the third day is water content = 75.16%, pH = 7.09, electrical conductivity = 552 Scm^{-1}, volatile solid = 76.45 %, C-Organic = 7.05%, N-Total = 0.433 %, P-Total= 0.147 mg P_2O_5/100 g, K-Total= 0.149 mg K_2O/100 g. It indicates that food waste can be recycled into useful products on a household scale within three days. The innovation of a composting device in a thermal composter can accelerate the composting of food waste at home. Household waste has various characteristics, so a thermal composter needs to be tested using food waste with varied compositions.

Acknowledgments

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