Continuous thermophilic composting process using heating lamps controlled by a microcontroller

by Bambang Ariantara -

IOP Conference Series: Earth and Environmental Science

Continuous thermophilic composting process using heating lamps controlled by a microcontroller

To cite this article: A Rochaeni *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **802** 012052

IOP Conf. Series: Earth and Environmental Science **802** (2021) 012052 doi:10.1088/1755-1315/802/1/012052

Continuous thermophilic composting process using heating lamps controlled by a microcontroller

A Rochaeni[1*], L Mulyatna[1], B Ariantara[2], M Fathul[1], W M Sagrim[1]

[1] Environmental Engineering Dept., Faculty of Engineering, Universitas Pasundan, Bandung 40153
[2] Mechanical Engineering Dept., Faculty of Engineering, Universitas Pasundan, Bandung 40153

anni_rochaeni@unpas.ac.id

Abstract. The natural composting process takes a long time because it goes through four phases of temperature levels. One of them is the thermophilic phase, where the largest rate of organic degradation occurs. The purpose of this study is to accelerate the composting process through temperature control. It was carried out using the Continuous Thermophilic Composting (CTC) method. The heating system was designed to provide the thermophilic temperature in the range of 50 - 65 °C. Arduino microcontroller was used to control the process temperature in real time. Several experiments were carried out to obtain the best design. In the first experiment, acrylic was used as the heating system wall with a 100 W incandescent lamp and a fan. The highest composting temperature produced was 38 °C on the 7th day. In the second experiment, two 100 W incandescent lamps were used to increase heat generation, and the highest composting process temperature was 41 °C. In the third experiment, 0.2 mm steel wall was used with two 100 W incandescent lamps and two fans, and the temperature of the composting process reached the thermophilic phase, namely 61°C on the 8th day.

1. Introduction

Composting is the process of decomposing organic waste under controlled conditions to produce a soil conditioner, compost, or organic fertilizer. Even though it is known as organic fertilizer, compost is not properly called fertilizer, considering that the nutrients it contains will depend on the characteristics of the raw materials used. Because municipal solid waste is very heterogeneous and fluctuating, the quality of compost will follow the characteristics of the waste used as compost at any time [1]. Aerobic composting is mostly done because it does not cause odour, the composting time is faster, the process temperature is higher. It can kill pathogenic bacteria and worm eggs so that the resulting compost is more hygienic [1]. Various technologies for the application of aerobic composting have been developed in Indonesia at the residential/environmental and household scale. In general, the quality of compost depends on the raw material. Organic waste sorted from sources (household) such as food scraps and garden waste is the best compost material. Kitchen waste or food scraps contain high organic matter levels such as dissolved sugars, flour, fats, proteins, cellulose and other components, which are highly biodegradable and generally contain a small amount of harmful bacteria [2]. Composting kitchen waste often requires additional NaOH to maintain alkalinity and pH 7 [3].

IOP Conf. Series: Earth and Environmental Science **802** (2021) 012052 doi:10.1088/1755-1315/802/1/012052

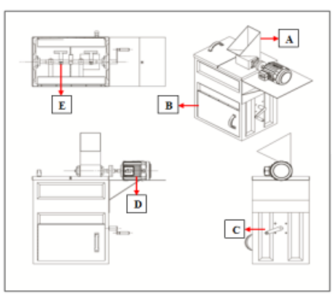
Various composter designs have been developed. The addition of air holes at the top or bottom will increase the convection aeration, but the organic decomposition will be concentrated in the bottom layer [4]. The continuous addition of waste also affects the quality of compost from kitchen waste [5]. Mixing kitchen waste with garden waste will result in a drier compost with nitrogen, phosphorus, and potassium content, representing a higher quality of soil follower [4]. For coffee waste, composter vermicomposting gives good results [6]. A bulking agent, waste load, and culture starter also give different composting results for kitchen waste [7]. The existence of supporting elements in the composting process such as Al, Ba, Ca, Co, Cr, and others also affect composting kitchen waste results [8]. Individual composter models have also been developed. A composter model has developed with 4 compartments (feeding, composting, compost dispensing, and leachate removal) equipped with an automatic mixer [9].

Continuous Thermophilic Composters (CTC) has been developed in terms of process, which are proven to accelerate the composting process [10-13]. Conventional composting has several disadvantages, namely larger investment, long processing time, and unstable product [10]. Apart from accelerating the composting process, CTC has also been shown to reduce pathogenic bacteria, integrons, and genera resistant to antibiotics [14] and produce beneficial fertilizers [13]. The various advantages of CTC result from changes in the bacterial and fungal communities in the composting process of CTC [10,15]. One study showed that CTC results after composting 14, 16 and 18 days obtained ripe compost with uniform quality and better than conventional composting for 28 days [10]. Other studies have shown that thermophilic composting of kitchen/food waste which is equipped with air intake, bacterial seeding and a stirrer can produce mature compost in 4 days, where temperatures of 50-60^{o}C occur at 8-12 hours and 50-65 hours [16]. The application of forced aeration on a composter shows that for a composter size of 1.05 liters, thermophilic composting occurs at an air rate of 0.05-0.1 liters/minute, meanwhile when using an air rate of 0.2-0.4 liter/minute will cause the process to run at a mesophilic temperature [17]. For a composter volume of 12 liters an air rate of 60 liters/minute was used [18].

This study aims to determine the performance of the CTC which applies incandescent lamps as a heater to reach the desired temperature and uses fans for additional aeration processes.

2. Methodology

The composter used is a design that has been made based on the results of the previous year's research, as shown in figure 1 below.



A: Waste chopper
B: Composting Room
C: Compost Mixing Lever
D: Chopper motor
E: Mixer

Figure 1. Pilot model automatic composter.

Using this composter, three experiments were carried out with air heating and airflow regulation to see the effect on the composting process.

2.1. Experiment 1: Using a 100 watt- lamp with two fan

The first experiment was carried out using a 100 watt lamp for heating the air and two fans to flow hot air from the heating room to the composting room. The lights and fans are housed in the acrylic-walled heating chamber. To prevent overheating of the compost which can cause the death of

IOP Conf. Series: Earth and Environmental Science **802** (2021) 012052 doi:10.1088/1755-1315/802/1/012052

microorganisms, the tool is equipped with an Autonics temperature controller. To see the composting process, the process temperature is measured with a K-type thermocouple 0.3 mm connected to the Arduino data acquisition system. The experimental setup is shown in figure 2 below.

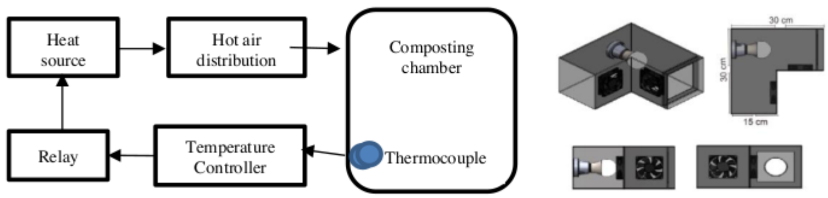


Figure 2. The first experimental setup.

2.2. Experiment 2: Using two 100 watt-incandescent lamps and two exhaust fans
Based on experiment 1, a second experiment was carried out by adding an incandescent lamp. In addition, compost pH measurements were also carried out using a pH sensor connected to the Arduino data acquisition system. Figure 3 shows the experimental setup 2.

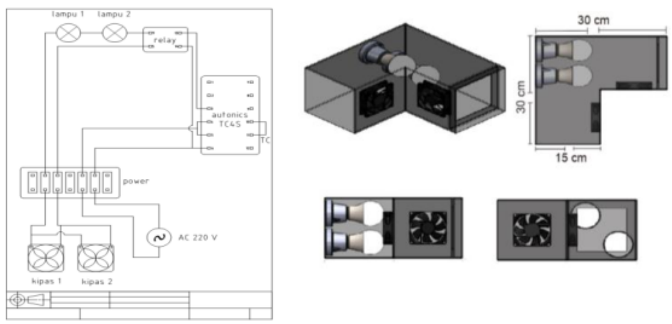


Figure 3. The second experimental setup.

After setting the heater is complete, the composting process is carried out for 21 days. The first and second experiments used kitchen waste taken from a canteen. Waste is fed into the composter as much as 1 kg/day according to daily habits in the household. Previously, the composter was filled with 10 kg of old compost as a starter. Every time new waste is entered, it is given EM4 bacteria at a dose of 8 ml/L. Waste is chopped with a chopper at the top of the tool and then the chopped waste goes into the composting room. The mixture of compost and garbage is stirred 10 times.

2.3. Experiment 3: Using two 100 watt-incandescent lamps with two exhaust fans
Based on the results of the second experiment, the third experiment was carried out by:

a. Changing the walls of the lamp room using steel.
b. Using two 100 watt-lamps, two exhaust fans directed downward, and a perforated cover at the inlet.
c. Using artificial waste with the same composition every day
d. Reducing the amount of starter compost at the beginning of composting, only 2 kg.

Figure 4 shows the modified drawing of a heating box using a steel sheet and two fans directed downwards and an additional perforated cover at the inlet.

.

IOP Conf. Series: Earth and Environmental Science **802** (2021) 012052 doi:10.1088/1755-1315/802/1/012052

Figure 4. Modified heating box and fan for the third experiment.

3. Results and discussion

The results of temperature measurements in the first experiment are shown in figure 5 below.

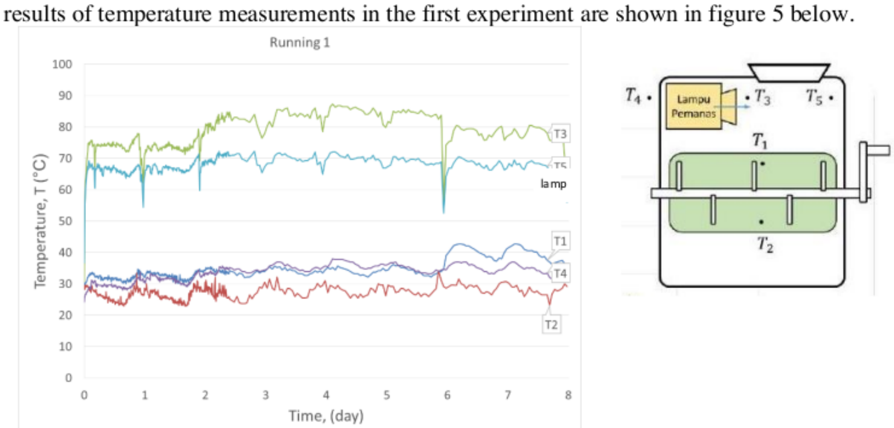


Figure 5. The results of temperature measurement in the first experiment.

The results above show that the composting process temperature (T_1) has not reached the thermophilic temperature (> 50°C). In comparison, the air temperature that comes out of the heating box (T_3) has reached a temperature> 75°C, and the composting room temperature is in the range of 60-70°C. These results indicate that air heating and circulation are not carried out effectively so that the thermophilic temperature is not reached.

The results of temperature measurements in the second experiment are shown in Figure 6 below. Meanwhile, the pH measurement results cannot be displayed because they are completely irregular. This happens because of compost inhomogeneity and the sensors used are too sensitive, so there is a very sharp change when stirring is done in the composting room.

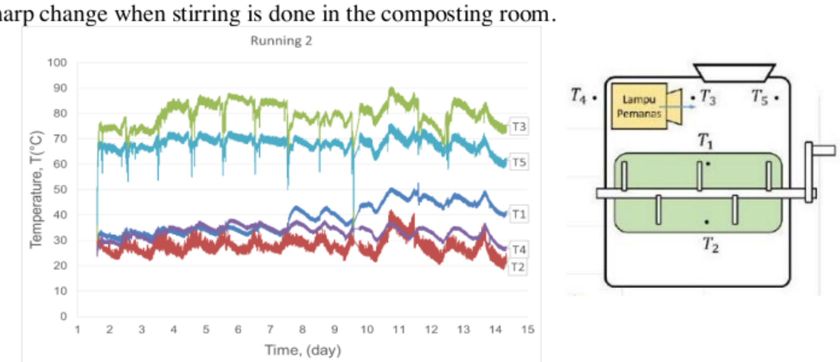


Figure 6. The results of temperature measurement in the second experiment.

IOP Conf. Series: Earth and Environmental Science **802** (2021) 012052 doi:10.1088/1755-1315/802/1/012052

In the second experiment, it can be seen that the compost temperature (T_1) has a significant increase on day 8, reaching 43°C, and continues to rise to 50°C on day 11. Then there is a decrease after day 14. This decrease in temperature may occur due to disturbances in the temperature sensor, so the temperature data from day 15 to the following days are irregular. Temperature T_3, which is the temperature of the air coming out of the heating box, can reach 80-90°C, while the temperature in the composting chamber (T5) only reaches 65-70°C. This result indicates that the heat loss from the composting room to the surroundings is quite high.

The low compost temperature achievement can also be caused by the C/N ratio of the mixture of waste and compost starter at the beginning of the composting process is not in optimal conditions. For this reason, the amount of old compost needs to be reduced in the next experiment. To support this statement, the next experiment will use artificial waste with a fixed composition every day. In addition, to increase heating effectiveness, the fan needs to be directed downwards towards the compost pile.

Food waste composition will affect composting time, maximum temperature, pH value, CO_2 evolution, and the percentage of material loss in the composting process [19]. From the analysis of 3 samples of canteen waste, it was found that the composition of artificial waste gave the best C/N value, namely 15% carrots, 30% mustard stalks, 10% cabbage, 20% spinach, 15% kale, and 10% potatoes. Examination of the composition of the waste resulted in a C/N ratio of 25.35. The requirement for the C/N value for optimal composting is 20-30 [20]. The results of temperature and pH observations in the third experiment are shown in figure 7 below.

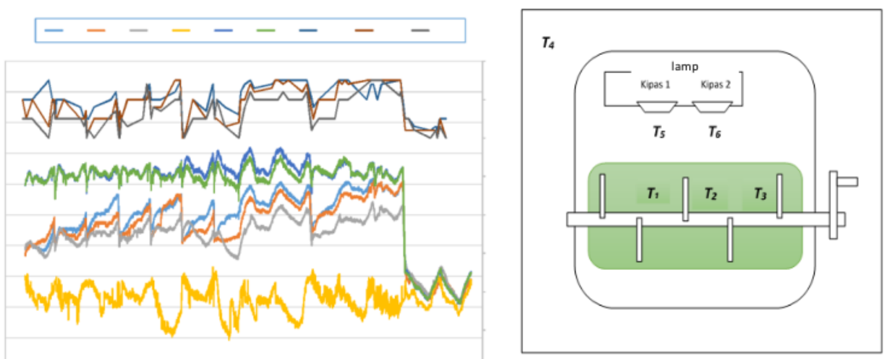


Figure 7. Temperature and pH in the third experiment.

From figure 7, it can be seen that the process enters the thermophilic phase (> 50°C) on 2nd day and reaches temperatures above 55°C on the 6th day, and the peak reaches a temperature of 61°C on 8th day and then is relatively constant on the following days at 55°C before loading new trash. The compost mixture during the experiment was dry and odorless. On the 14th day the heater is turned off (the fan remains on) to see the composting process without heating. It appears that the lowest temperature reaches 30°C. At the end of the experiment, the compost mixture looked slightly damp.

From the results of pH measurements, it can be seen that the pH rises to above 7.5 when the temperature rises. After stirring with new waste, the pH value always decreases until it reaches a pH value of 6. Then the pH increases with increasing temperature. When the temperature increases and reaches a constant value, the pH is also relatively constant at 7.5. The decrease in pH at the entry of waste is due to the relatively low pH of the waste. Waste with low pH will slow down the transition process from mesophilic to thermophilic [21].

The results of measurement of characteristics of waste, starter compost and mature compost in the third experiment are shown in table 1 below.

Table 1. Chemical characteristics of waste, starter compost and mature compost in the third experiment.

No	Parameter	Method	Unit	Waste	Starter	Compost
1	Water content	ASTM D2216-80	%	90.13	15.77	48.60
2	Phosphate	ASTM D2216-80	%	90.25	50.22	59.75
3	C-Organic	SMEWW-5520-B	%	63.89	66.75	28.66
4	NTK	SMEWW-4500-N org-B	%	2.52	2.15	2.66

The C/N ratio is the ratio of the elements carbon (C) and nitrogen (N) associated with the metabolism of decomposing microorganisms in the composting process. During the composting process, decomposing microorganisms need carbon (C) as an energy source and nitrogen (N) as a substance to form microorganism cells. If the C/N ratio is high, decomposing microorganisms will run slowly to decompose compost organic matter so that the composting time will be longer. Meanwhile, if the C/N ratio is low, nitrogen, an important component in compost, will be released into ammonia and cause a bad smell in the compost [22]. Based on the results of the analysis, the C/N ratio of waste was 25.35. The C/N ratio value of the starter fertilizer of 31.04 does not meet the compost quality standards in SNI 19-7030-2004. Mature compost has a C/N ratio of 10-20. If the C/N ratio is higher, the compost is not ripe enough and will take longer to decompose. In this condition, the compost produced is still half-ripe and not suitable for direct use on plants because the C/N ratio is still high and not up to standard. Meanwhile, the C/N ratio of ripe compost from the third experiment of 10.77 has met the compost quality standards set by *SNI* 19-7030-2004.

4. Conclusion

Referring to the results of the third experiment, the lamp can be an alternative heater for the composting process using the Continous Thermophilic Composting (CTC) method so that the process runs in a thermophilic phase and the composting process becomes faster. The temperature is regulated not more than 60^{o}C using a microcontroller. Two fans also function to circulate hot air by adjusting the direction of the fan. The compost quality obtained has met the compost quality standards

References:

[1] Damanhuri E 2005 *Expert Meeting on Waste Management in Asia-Pacific Islands*
[2] Benjawan L, Sihawong S, Chayaprasert W and Liamlaem W 2015 *Compost SciUtil* **23** 11-17
[3] Gill S S, Jana A, and Shrivastav A 2021 J *Microbiol Biotechnol Food Sci* 477-483
[4] Adhikari B K, Trémier A and Barrington S 2012 *Environ Technol* **33** 2383-2393
[5] Hwang E J, Shin H S and Tay J H 2002 *Waste Manag Res* **20** 119-126
[6] Yu Z, Tang J, Liao H, Liu X, Zhou P, Chen Z, Rensing C and Zhou S 2018 *Bioresour Technol* **265** 146-154
[7] Abdullah N, Chin N L, Mokhtar M N and Taip F S 2013 *IntJRecycl OrgWaste Agric* **2** 1-10
[8] Evans G and Tan P 1998 *ArchEnvironContamToxicol* **34** 323-329
[9] Papadopoulos A, Stylianou M, Michalopoulos C, Moustakas K, Hapeshis K, Vogiatzidaki E, and Loizidou M 2009 *Waste Manag* **29** 204-213
[10] Xiao Y, Zeng G M, Yang Z H, Shi W J, Huang C, Fan C Z and Xu Z Y 2009 *Bioresour Technol* **100** 4807-4813
[11] Schulze K 1962 *ApplMicrobiol* **10** 108-122
[12] Elango D, Thinakaran N, Panneerselvam P and Sivanesan S 2009 *ApplEnergy* **86** 663-668
[13] Waqas M, Almeelbi T and Nizami A S 2018 *EnvironSciPollutRes* **25** 5212-5222
[14] Qian X, Sun W, Gu J, Wang X J, Zhang Y J, Duan M L, Li H C and Zhang R R 2016 *BioresourTechnol* **220** 425-432
[15] Li X, Shi X S, Lu M Y, Zhao Y Z, Li X, Peng H and Guo R B 2019 *BioresourTechnol* **294** 122044
[16] Chang J I, Tsai J and Wu K 2006 *BioresourTechnol* **97** 116-122

[17] Lu S, Imai T, Li H, Ukita M, Sekine M and Higuchi T 2001 *EnvironTechnol* **22** 1177-1182
[18] Suler D and Finstein M 1977 *ApplEnvironMicrobiol* **33** 345-350
[19] Chang J I and Hsu T-E 2008 *BioresourTechnol* **99** 8068-8074
[20] Damanhuri E 2017 *State of the 3Rs in Asia and the Pacific UN center for Reg Dev Nagoya*
[21] Sundberg C, Smårs S and Jönsson H 2004 *BioresourTechnol* **95** 145-150
[22] Zhu N 2007 *BioresourTechnol* **98** 9-13

Continuous thermophilic composting process using heating lamps controlled by a microcontroller

ORIGINALITY REPORT

16%	15%	14%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

8%

★ researchmap.jp

Internet Source

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		