Environmental Research & Technology, Vol. 4 (2), pp. 184-189, 2021

Turkish JournalPark ACADEMIC

Environmental Research & Technology

http://dergipark.gov.tr/ert

RESEARCH ARTICLE

Performance evaluation of a non-odorous compost barrel for household purposes

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ABSTRACT

Composting is one of the simplest and oldest methods for reducing biowaste at source before it goes to the main waste stream. However, odor from the degradation procedure can be a significant problem, which can hinder household to pursue this kind of endeavor. This study aimed to evaluate the composting barrel using a covering device to mitigate the emission of foul odor during composting of typical household biowaste. Turning the substrates inside the barrel is recommended, but the effect of turning frequency needs additional discussion. Hence, two barrels with the same capacity were used in the study for comparison. Barrel A was turned daily while Barrel B was turned once a week, both with five complete rotations. Results showed that compost from Barrel A could be harvested earlier than Barrel B, as a result of the higher turning rate. Composting parameters such as temperature, pH, moisture content, and mass variations were carefully monitored and exhibited acceptable operating conditions.

In terms of the quality of the final compost, the former had a total Nitrogen, Phosphorous, and Potassium (NPK) of 4.67 %, while the latter has a total NPK of 4.86 %, which are both classified as soil conditioners based on the standard for organic soil amendments. Moreover, the activated carbon (AC) mat cover was found to be effective ($p<0.05$) in deterring odor in the course of the decomposition process. Hence, this study demonstrates that the composting can be a non-odorous and eco-friendly solution for household's biodegradable waste management.

Keywords: Compost barrel, turning, non-odorous, soil conditioner, household composting

1. INTRODUCTION

In the Philippines, biodegradable or organic waste contributes the largest percentage (52.31%) of its total municipal solid waste, which produces leachates that can be odorous and harmful to the environment [1]. Improper disposal of these wastes to open dump sites results in the contamination of groundwater resources and soil [2]. To avoid this problem, the community must focus on treating biodegradable solid waste at the source [3]. The method of household composting is not new in the management of solid waste. It is one of the cheapest techniques in the reduction of biowaste at source. Composting at home also encourages family members to segregate their waste as biodegradable and non-biodegradable. Moreover, it has the potential to enhance rural/urban people's economic conditions through backyard gardening, marketing of their compost and recyclables [4].

Nowadays, there are various types of composting methods for biodegradable waste: from the traditional compost pit, which has been a common method in rural areas, to simple tire composters, and more complex designs like rotating barrels [5]. However, in urban areas, there is a strong preference for compost barrels because of the less space they occupy. Rotating barrels is an efficient and promising decentralized composting approach, which involves aeration and mixing of compost materials to produce a quality byproduct [6]. Either way, odor is recognized as a contentious issue in composting, which has been labeled as composting's "achilles heel" [7]. Compounds causing foul odors present at low concentrations do not cause much illness, but excessive odor can result in symptoms such as nausea [8]. Odor, which is caused by the breakdown

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Received 30 December 2020; Accepted 5 June 2021
Available Online 21 June 2021
Doi: https://doi.org/10.35208/ert.848129

This paper has been presented at EurAsia Waste Management Symposium 2020, Istanbul, Turkey

process of biodegradables that can be minimized using methods such as absorption, adsorption, and bio filtration [9]. Fresh compost products and activated carbon (AC) are examples of biofiltering medium, which can be used as an odor controller during the composting process [10, 11]. However, limited literature is available on the investigation of activated carbon used as in-situ biofiltration during composting. Dyer [11] mentioned that activated carbon or charcoal can be mixed with the compost substrates to neutralize odor, but no literature has been found to use activated carbon (AC) as a cover mat to prevent odor emission in compost barrels.

Aeration is also one of the methods to control odorous compounds and an integral part of the over-all compost procedure because it stimulates microbial degradation of organic matter [12]. The turning of compost materials inside an enclosed reactor, which involves rotating the compost barrel, is the most common aeration technique [6]. However, excessive or lack of aeration has a major effect on the compost parameters and the quality of the final compost [13]. Thus, several studies were conducted to determine the effect of turning frequencies on biowaste composting but few literatures were seen regarding the number of turnings for rotating barrels. Most researchers agreed that turning the compost yielded better result compared to without or no turning treatment [14, 15]. Kalamdhad and Kazmi [6] recommended once a day turning of compost barrel to produce stable compost output. Another experiment conducted by Boyle[16], states that there is little to no effect on the quality of the compost between every 3 days and every week turning. To fill this gap, a comparison between daily turning and weekly turning needs further analysis. This study therefore aims to evaluate the composting process inside the composting barrel with the application of AC used as cover mat to mitigate the smelly odor that comes out from the barrel's aeration holes. Moreover, it seeks to determine whether the frequency of turnings will have a significant effect on the compost parameters and physio-chemical quality of the end product.

2. MATERIALS AND METHOD

2.1. Compost barrel with AC mat cover

A 114-liter recycled HDPE plastic drum is selected as the compost barrel that can accommodate an estimated 30-40 kg of biodegradable household wastes. For aeration, 5.08-cm holes are drilled at the top and 0.79-cm diameter holes at the bottom to serve as an outlet for the leachates, which is collected in a basin. Fine screens were attached to the surface of the holes in order to prevent flies, insects, and rodents from entering the bin. The odor control cover mat (60 x 50 cm) was a fabric material sewn into four equal portion and was filled with a total of two kilograms activated carbon (AC), as seen in Fig.1. The AC cover mat was placed over the top of the barrel, covering the aeration holes. Inside the barrel are four baffles installed to enhance mixing. A steel frame with four rollers is fabricated to support the barrel's full weight and to ensure proper turning. The completed compost barrel is seen in Fig. 2 is placed in an open area occupying approximately one square meter of space where it is protected from rainwater.

Fig 1. The mat cover filled with activated carbon

Fig 2. Barrel A with odor control cover (left) and Barrel B without cover (right)

2.2. Preparation of compost materials

Good compost usually contains carbon (brown) and nitrogen (green) materials. Green substrates come from vegetable peelings, fruit rinds, and small discarded pieces of meat, fish, and poultry, while brown material used was sawdust from Saint Louis University's carpentry shop. The green materials for the composting procedure are chopped into pieces that were collected from seven households in an apartment complex. The compost materials were mixed with an initial carbon to nitrogen ratio of 22:1. The mixed organic substrates were loaded in the two barrels with 40 kgs for each unit, filling up to 50% of each barrel's total capacity for aeration purposes.

2.3. Experimental analysis

The experimental procedure was conducted by fixing the frequency of turning the compost unit. Barrel A was set to rotate (5 rotations) daily while the same five rotations also turn barrel B but only during the weekend (once a week). Five rotations were made to ensure proper mixing and aeration of biomaterials inside the composting unit. The temperature parameter was monitored daily using a standard glass thermometer inserted 3 to 5 inches in three different points inside the compost, wherein the reading is equilibrated for 5 minutes [17]. Ten grams of each sample were grabbed from three different points without disturbing the adjacent materials. A triplicate sample was collected and analyzed for pH and moisture content. The daily pH variation of compost was determined by H18733 pH meter, while the weekly moisture content of the sample was determined after drying 24 h at 105 °C. The mass variation of each compost was determined using gravimetric weighing scales. The final composts samples from both barrels were brought in standard soil laboratory for analysis. Total nitrogen was determined using the Kjeldahl method; total phosphorous, vanadomolybdate method; total organic carbon, based on ash content using standard equation; total potassium, flame atomic emission spectroscopy method.

2.4. Odor evaluation and statistical analysis

The AC cover mat was placed over the top of the barrel every after turning, where it covers the aeration holes, as shown in Fig. 2. The compost barrel's level of the odor was evaluated weekly by the representative of the seven households using a 7-point odor intensity Likert scale throughout the composting process. The respondents standing within 1 meter distance were asked to rate the odor intensity from both barrels with and without the odor control cover, with 0-no odor, 1-very weak (odor threshold), 2-weak, 3-distinct, 4-strong, 5-very strong, and 6-intolerable [18]. To determine the effectiveness of the odor control cover mat and the effect of frequency of turning on compost parameters, a paired t-test ($p<0.05$) was performed using the real-stat add-ins in Microsoft excel.

3. RESULTS AND DISCUSSION

3.1. The compost parameters

Temperature is an important parameter which reflects the breakdown of compost materials, metabolism microorganisms, and the efficiency of the composting process [19]. The temperature profile of the two compost barrels as a function of time is shown in Fig. 3, with an ambient temperature of 23°C. The two composting barrels showed an increase in temperature that depicts the stages of the composting process which is the mesophilic phase (ambient temperature to 40°C), thermophilic phase (above 40°C) and cooling stage (below 40 °C to ambient temperature) [20, 21]. The rapid rise in temperature at the initial stage was due to the biodegradation of an adequate amount of substrate, which causes the activation of microorganisms. The optimum range of temperatures for the composting process is 40-65°C, with 55-60 °C as the most favorable for the pasteurization of pathogens [22, 23]. Results showed that both composts have reached the thermophilic stage of composting with barrel A peak temperature of 48 °C and barrel B rise to a maximum temperature of 45°C. Barrel A's higher peak temperature compared to barrel B is attributed to the frequency of turning. Higher temperature corresponds to a greater rate of turning as supported by Zhou [14]. In contrast, the lower temperature was linked to a lesser number of turning yielding to an insufficient supply of oxygen. An observation on compost barrel B showed an increase in temperature caused by the activation of microorganisms after it was turned [24]. After the thermophilic stage, all barrels manifested a gradual decrease in temperature until they return to the normal ambient condition, due to lesser microbial activity [25]. Barrel A returns to ambient temperature after 18 days, in which, the decrease of temperature towards ambient condition can be an initial sign to harvest the compost, ready for maturation. The compost from barrel B has conformed to its surrounding temperature on the 21st day until the end of composting. Although, both barrels did not reach the ideal temperature at 55°C, still, they fall into the acceptable range of composting process. Moreover, the effect of frequency of turning showed a significant difference (p-value <0.05) in the temperature profile of the compost barrels (Table 1). Previous literature also reported similar significance about the turning frequencies on temperature during composting [6, 26].

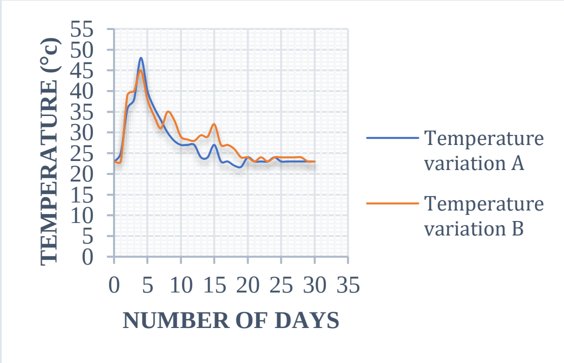

Fig 3. The temperature profile in Barrels A and B throughout the composting process

pH is a factor that is associated with the odor emission during composting [27]. The normal range of pH during the composting process should be around 5.5 to 8.5, with pH seven as the most ideal [22]. The variations of pH on the compost barrels are shown in Fig. 4. Results showed a rapid decline of pH during the initial composting procedure in both barrels. This was due to the fermentation of organic matter that turns the compost to be acidic, which causes an odor problem and even inhibit the process of degradation [27, 28]. Nonetheless, the pH progresses towards the ideal pH range until the end of the composting process. The increase in the compost pH after the sudden decrease was due to the biodegraded lactic and acetic acids caused by the transition from mesophilic to the thermophilic stage [28, 29]. Moreover, the study showed a significant difference in pH variation (p-value <0.05) with the turning frequency of compost barrel (Table 1).

Fig 4. Variation in pH values as composting progress

Moisture Content is an essential parameter in aerobic composting, influencing microorganisms' activity during the process [30]. The amount of compost moisture in each barrel is shown in Fig.5. During composting, the initial moisture content is higher than the recommended moisture of 40-60% [30]. This leads to anaerobic conditions (humidity higher than 65%) during the initial composting phase, contributing to a lower pH and the generation of leachate and foul odor [21]. But as the degradation process continues, the moisture content of compost from each barrel gradually decreases towards the recommended ideal moisture level (50%) [31]. This moisture loss was associated with the increase in compost temperature [32]. In this study, it was found that there is no significant effect of the frequency of turning in the moisture profile. Nevertheless, the moisture falls under the optimum humidity during the second week of composting up to the latter part of the process.

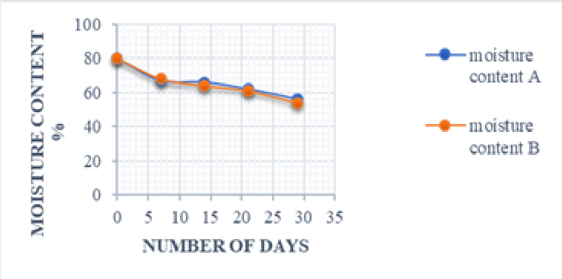

Fig 5. Moisture content variation during decomposition

The mass reduction during the composting process is shown in Figure 6. The mass of the compost is also a significant parameter of composting since it depicts the weight reduction of biomaterials used. Both barrels performed well in the reduction of weight of the biomass, which resulted in about 65 – 70% mass reduction. Results showed that both barrels exceeded the expected mass loss (between 30% to 60%) of Diaz et al. [33] However, no significant change was observed between the gravimetric weight of both composts (Table 1).

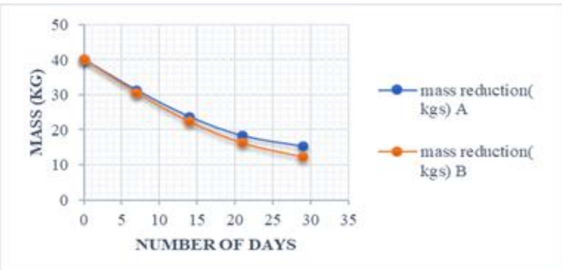

Fig 6. Mass reduction during decomposition

Table 1. Mean and p-value with significant difference

Properties	Barrel A	Barrel B	P-value	Significance at P<0.05
Temperature	27.0097	28.4074	0.0029*	Yes
pH	6.6290	7	0.0005*	Yes
Moisture Content	66.2	65.4	0.2420	No
Mass	25.7	24.26	0.0515	No
Odor emission	2.85714	2.5714	0.1723	No

3.2. Odor

In terms of odor evaluation, Fig. 7 and 8 below showed a significant effect (p-value,0.0007 <0.05) in the reduction of foul odor during the decomposition process because of the usage of activated carbon cover mat. The substantial decrease of the odor was mainly due to the adsorptive property of the activated carbon. Nevertheless, the high odor emission during the first week does not significantly change concerning the frequency of turning, as shown in Table 1. The odor is associated with the pH level of the compost materials. According to Sundberg et al. [27], high odor emissions shown in the figures below were due to low pH, especially during the initial composting stage. To reduce odor emission, Sundberg et al. proposed that the pH should be increased via aeration and usage of additives. At any rate, during the third and fourth weeks of composting, the odor level detected by the respondents decreases even without AC probably because of less microbial activity as observed in the curing stage and due to the increase of their pH. Nonetheless, the AC cover mat's application resulted in an almost zero odor intensity up to the end of the composting process.

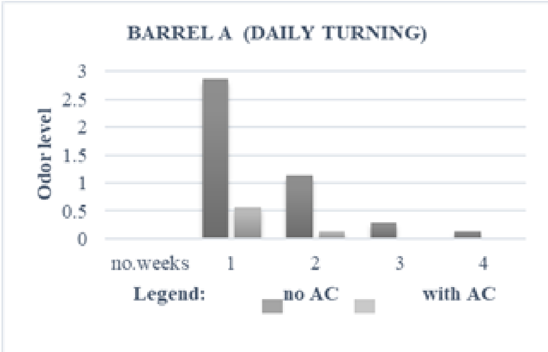

Fig 7. Odor level of Barrel A with and without AC covers

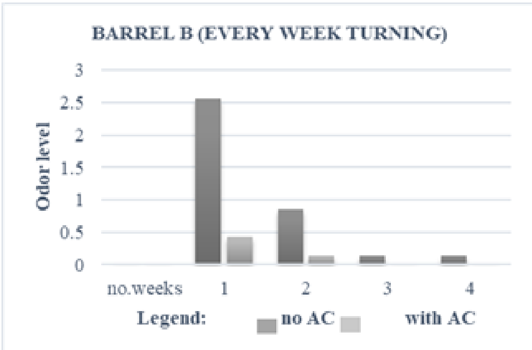

Fig 8. Odor levels of Barrel B with and without AC

3.3. Quality of the compost output

The table below shows the summary regarding the quality of compost output, based on the Philippine National Standard for organic soil amendments [34]. The study showed that both composts from barrel A and B fall under the category of soil conditioner in terms of total NPK. It revealed that over-all, there is no significant effect of turning frequency to the quality of compost, which is similar also in the study of Page [16]. The only noteworthy observation was that compost from barrel A has lower carbon to nitrogen (C/N) ratio compares barrel B. The lower C/N ratio was associated to a higher frequency of turning in barrel A as a result of the volatilization of N as NH3 and C as CO2 [26]. Nevertheless, the carbon to nitrogen (C/N) ratio decreasing pattern from 22:1 to 12:1 (barrel A) and 18:1 (barrel B) indicates the formation of a stable and matured compost, as can also be seen in the previous literatures [14, 26]. With regards to the moisture content (MC), color, consistency, and odor, the finished compost fall under organic fertilizer or soil conditioner.

Table 2. Summary of compost output parameters

Properties	Organic Fertilizer	Soil Conditioner	Compost A	Compost B
Total N-P_2O_5-K_2O	5-10%	2.5-5%	4.67%	4.86%
C/N	10:1-20:1	10:1-20:1	12:1	18:1
MC	10-35%	10-35%	16.91 %	15.11%
Color	Brown to black	Brown to black	Brown to black	Brown to black
Consistency	Friable	Friable	Friable	Friable
Odor	No foul odor	No foul odor	No foul odor	No foul odor

4. CONCLUSIONS AND RECOMMENDATIONS

The amalgamation of this study's findings establishes that composting can significantly reduce biodegradable waste at source and convert it to a quality compost product. The physio-chemical analysis of the mature compost from both barrels is in the range for soil conditioners that can improve soil conditions for an effective plant nutrient uptake. The frequency of turnings did not significantly affect the quality of the end-compost as long as adequate aeration (5 rotations) is provided. However, the turning rate significantly affects temperature and pH during the decomposition process. Daily turning makes oxygen more available, resulting in a faster-composting process, which is why compost from barrel A can be harvested earlier than barrel B. The odor-controlling media contributes to the reduction of odor and found to be effective in mitigating foul smell during the composting process. The other source of the offensive odor was leachates produced; therefore, it is necessary to discard it regularly. The barrel designed in this study can be an alternative composting method suitable for urban areas with limited space (at least 1 square meter is required), without affecting the adjacent household due to its odor absorbent feature. This research endeavor showed a humble attempt to evaluate a composting barrel, which can be a practical, non-odorous, and eco-friendly solution in biodegradable solid waste management for household purposes.

ACKNOWLEDGMENT

The authors would like to thank the Department of Agriculture, San Fernando City, La Union, for the testing apparatuses. For God's greater glory.

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