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Development and Testing of Hand-Operated Small-Scale Composter in Composting Biodegradable Waste

J.A. Bellen[1*], S.K.L. Sta. Maria[2], P.M.C. Winterstien[3], F.A.L. Chavez[4], J.A. Bellen[5]

[1,2,3,4] Visayas State University, Baybay City, Philippines
[5] Mindoro State College of Agriculture and Technology, Oriental Mindoro, Philippines

[*]*Corresponding Author: joy.bellen@vsu.edu.ph*

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***Abstract*—**Environmental laws promote the creation of environment-friendly technology. Biodegradable waste constitutes big proportion of solid waste. In solid waste management, composting is a viable preference. This study aimed to develop a hand-operated composter for the biodegradable waste. Results showed that in waste analysis and characterization study an average waste generated was 6.25 kg per day with 80% biodegradable, 13% recyclable and 7% residual waste. A drum-type hand-operated small-scale composter was developed with a feeding capacity of 15 kg. During testing, active composting stage, though short-lived, thermophilic condition was observed in the first four days. The mature compost has dark brown color and there was no foul odor. The composter can be alternative technology for community-based solid waste management practices. Further studies should be conducted on these aspects: thermophilic condition; seed compost; aeration holes in the drum; and soil analyses for the mature compost to determine its suitability for organic farming**.**

Keywords*—WACS, solid waste management, hand-operated, small-scale composter*

I. INTRODUCTION

Waste reduction at the source is one of the suggested actions of the Philippine Ecological Solid Waste Management Act (Republic Act No. 9003). As a result, researches were made on the innovative technology that can reduce solid waste. Despite continued efforts, evidence showed that RA 9003 remains yet to be fully implemented. For example, reports showed that the solid waste management practices of some households in parts of Manila [1] and Cebu [2] were focused on awareness level. The volume of solid waste is alarming. In the Philippines at a national scale, an estimated 35,000 tons is produced per day. In Region 8, an estimated 1,400 tons per day is produced [3]. The dilemma of solid waste management is also documented in India [4], [5]. For example, [4] reported that proper municipal solid waste disposal systems were relatively deficient. Studies have shown that the volume of waste is generally 50% highly-organic (biodegradable) and recyclable [6], [7]. Technology for composting biodegradable waste into usable compost is necessary.

The literature reveals that small scale composting was an effective solution to reduce the waste [7], [8]. Reference [8] introduced motorized small-scale composter suitable for the material recovery facilities (MRFs) in barangays, villages, government agencies, and academic institutions. The Department of Science and Technology (DOST), observed that the waste generated is less than the required nominal capacity of 500 kg d^{-1} to run the bioreactor. To address the need, [8] developed a motorized small-scale composter that can handle small amount of waste generated in the site.

In areas where motor is limited and electricity is scarce, a hand-operated composter can serve as an alternative technology for management of small volume of biodegradable waste. The development of a hand-operated small scale composter is a significant contribution to composting organic material into usable compost [7], [8]. This study furthers the development of hand-operated small-scale composter made from recycled materials.

Generally, the study aims to develop a hand-operated small-scale composter that can help in composting in a basic education institution. Specifically, the study aims to: (1) determine the amount of waste generated daily at basic education institution (BEI), (2) develop hand-operated composter suitable for solid waste generated from BEI and (3) test the efficiency of the hand-operated small-scale composter. The rest of the paper is organized as follows, Section I contains the introduction of development and testing of hand-operated small-scale composter, Section II contains the related work of developing composter, Section

III contains the measures of developing and testing composter, Section IV describes results and discussion and Section V contains the recommendation and concludes research work with future directions.

II. Related Work

Using waste analysis and characterization study (WACS) waste composition, quantity, and bulk density can be determined [8], [9]. In WACS, collected samples were manually sorted into categories such as biodegradable, residual, recyclable, inert and special wastes. In waste quantity analysis, the collected samples were weighed as basis to calculate the volume of waste disposed per week. In bulk density analysis, the ratio of the weight of per unit volume of the collected sample was determined. Knowledge of the characteristics of the waste is very important for effective, long term, waste management planning. The WACS result can be the basis of the design and fabrication of the composter. Reference [8] calculated the biodegradable waste as basis for the size of the composter. In their study, 48 kg d^{-1} was average amount of waste, so they built a 50 kg drum-type composter made of high density plastic. The strategy suggests that available material such as scrap metals can used to create the composter.

The efficiency of the composter can be tested through several parameters. Temperature is a crucial element; the rapid rise of temperature indicates microbial activity. Thermophilic condition is evident at 40-60°C [8], [10]. Physical properties (i.e., color and odor) are indicators of effective composting. The compost product should have dark brown to black color with no foul odor [8].

III. Methodology

Waste Analysis and Characterization Study (WACS)

Characterization of solid waste was conducted using waste analysis and characterization study [8] to determine the composition of solid waste generated in Visca Foundation Elementary School (VFES) grounds. The daily amount of different kinds of solid wastes, specifically biodegradable wastes, serve as basis for the design of small scale composter [8]. Waste were collected daily for five days from VFES ground and classrooms. Collection record showed a total of 6.5 k of biodegradable waste. These were brought to the compost pit built inside the school campus. Total volume of garbage pile was determined by multiplying the total area by the height of the garbage pile.

Design and fabrication of hand-operated small scale composter

Wastes were unpacked, and mixed. The amount of biodegradable waste served as basis for determining the capacity of composter. A 15 kg capacity white plastic drum (high density polyethylene) was used for the fabrication of composter. The composter has 3 basic parts 1) the drum which holds the composting mixture, 2) a metal stand to support the container and allows the drum to rotate, and 3) a gear for rotating the drum and allow mixing of materials. The composter drum has an opening for loading and unloading materials. The opening was made of plastic cut portion of the drum. Attached to the opening were metal locked and hinges. Attached to the opposite sides of the drum were metal shafts welded to round plates. The welded plates with shafts were attached to the drum by several bolts and nuts. The stand to support the composting drum was fabricated using angular bars. A bicycle chain was fixed to the two gears (Figure 2).

Seed compost and in-vessel composting

Seed compost was collected from compost pile of biodegradable waste. Raw materials for start-up operation consisted of pulverized rice ("tahop" in local name), dried waste and seed compost at a ratio of 2:2:1 [8]. Rice bran served as nutrient source for microorganism. The total mixture composed of 5 kg biodegradable waste, 5 kg rice bran, and 2.5 kg seed compost. The biodegradable waste was manually shredded to reduce particle size. The total mixture was 15 kg. The composter was rotated for 8 hours (h) daily. Substrate retention time was 4 days inside the composter. After which, raw compost was unloaded and transferred to another container in curing area for further degradation and maturation of materials.

Pile composting and curing

The partially composted material from in-vessel composting was regularly turned and temperature of substrate was daily monitored. Reference [8] recommended that the moisture active pile composting should be maintained at 50-60°C by adding water and turning occasionally. Temperature of pile was monitored using thermometer. Compost was considered mature when the temperature of the pile was nearly ambient [8]. Mature compost was sieved using wire screen ($9mm^2$). Grab samples were examined for physical properties such as color and odor [11].

Data analysis

Means of waste characterization data such as total weight, total volume, and bulk density were obtained after five days WACS. Three composting operations were done to determine the efficiency of fabricated composter. The color and odor of the compost were compared against Philippine National Standards for Organic Agriculture [11].

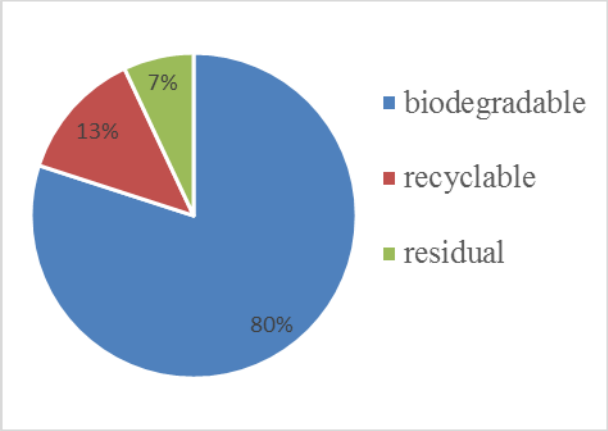
IV. Results and Discussion

Waste Analysis and Characterization Study (WACS)

The waste generation per day, total volume and bulk density for five-day WACS is shown in Table 1. The composition of wastes by type is shown in Figure 1. The highest amount of and volume of waste was observed at day 1 (Monday) due to the accumulated wastes during weekend. The largest proportion was biodegradable waste (80%), and recyclable (13%) and the remaining was residual wastes (7%). Much of the biodegradable wastes were yard waste (75%) and soiled paper (25%) from the classrooms. Based on the total collected wastes of 6.25 kg d^{-1} and 80% was biodegradable waste. The average potential material for composting was 5 kg d^{-1}.

Figure 1. Percent composition of waste generated.

A drum-type hand-operated composter was developed to utilize the biodegradable waste generated in VFES into compost, a useful product. Based on the WACS



result, VFES generates about 5 kg d^{-1} of biodegradable waste. Therefore it is ideal for small scale composter.

Table 1. Amount of waste generated in VFES

Day	Total Weight (kg d^{-1})	Total Volume (m^3)	Bulk Density (kg m^{-3})
1	9.00	0.45	20.00
2	6.50	0.35	18.57
3	6.00	0.42	14.28
4	4.25	0.30	14.17
5	5.50	0.31	17.42
Average	6.25	0.36	16.89

Figure 1. Percent composition of waste generated.

Design and fabrication of composter

The biodegradable waste was 5 k per day. The ratio was 5 kg biodegradable waste, 5 kg rice bran and 2.5 kg seed compost. The mixture was 12.5 kg. A drum-type hand-operated small-scale composter was developed with a feeding capacity of 15 kg (Figure 2).

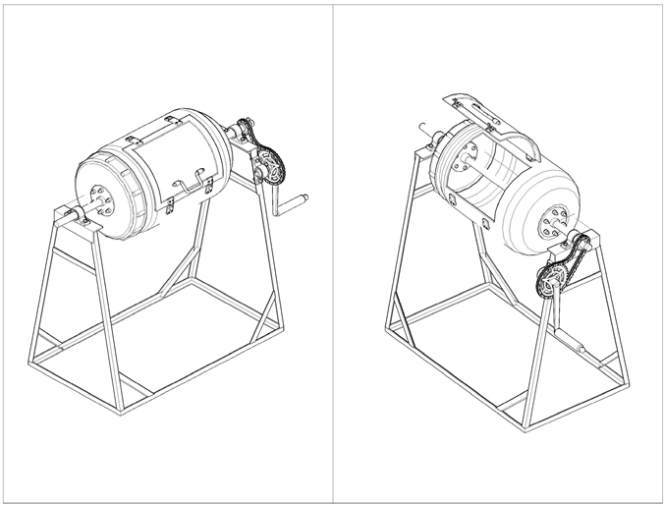


Figure 2. The assembly of the hand-operated small-scale composter.

Temperature profile during composting operations and compost analysis

The composting trials were conducted and the temperature profile during the composting operations is shown in Figure 3. Thermophilic condition was observed after 1 to 4 days of loading the initial mixture into the composter. High temperature was recorded for the first week during pile composting and curing stage. Temperature of 43°C was observed for the first four days during the active composting period. Composts produced from the first composting trial were dark brown, humus-like, and without foul odor [11].

Temperature is an important parameter that affects the success of composting. The temperature profile was typical in composting operation. Thermophilic condition was observed indicating active microbial activity and proper condition. Heat generated during composting is due to the microbial action on organic materials. The heat they produce causes the compost temperature to rapidly rise. Initial decomposition is carried out by mesophilic microorganisms that rapidly break down the readily degradable compounds. As temperature rises above 40°C mesophilic microorganisms become less competitive and are replaced by thermophilic microorganisms. Faster decomposition occurs during thermophilic stage of composting (40-60°C). Temperature above 60°C slows down the composting process as beneficial microbes tend to die off [10]. Turning and adding water to the file when it gets too hot help lower the temperature. In this study, it was observed that the thermophilic condition was low and observed for few days suggest that few thermophilic microorganisms but more abundant in mesophilic microorganisms are available. Few thermophilic microorganisms can be attributed to two possible errors. The composter lacked the aeration holes in the drum which can

provide oxygen for aerobic respiration [8]. In order to profile the microorganisms, seed compost should be tested for microbial activity.

The fabricated hand operated composter was used in vessel composting (4 days). The next step was active pile composting (2 to 3 weeks) and curing phase in a separate container. The initial degradation of materials was hastened through the composter with slow rotation for 8 h d^{-1}. There was no foul odor observed during the composting operations and the mature compost has dark brown color. These indicate that the process is within the Philippine national standards for organic agriculture [11].

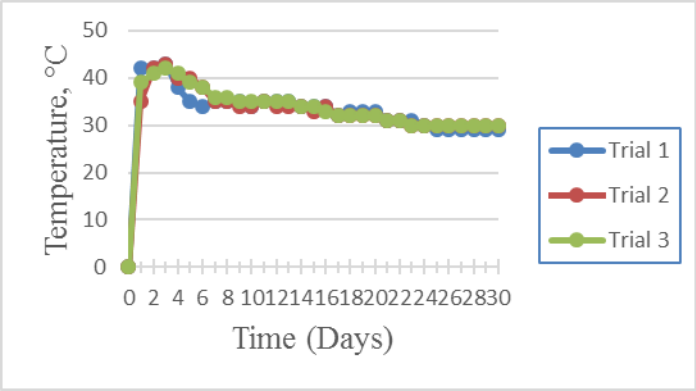


Figure 3. Temperature profile during composting operations

V. Conclusion and Future Scope

The study revealed an average daily solid waste generated was 6.25 kg. Biodegradable waste constitutes 80% of these wastes which resulted to 5 kg d^{-1}. Based on the amount of biodegradable waste, a hand-operated small-scale composter was fabricated using plastic drum with a feeding capacity of 15 kg. The test revealed that thermophilic condition was achieved during active composting. The composter unit was portable, minimal cost, needs limited manpower, and easy to operate. The developed hand-operated composter is very applicable to communities that generate small volume of biodegradable waste.

In order to enhance the hand-operated small-scale composter, further studies should be conducted on these aspects: thermophilic condition, seed compost, aeration holes, and soil analyses for the mature compost to determine its suitability for organic farming.

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AUTHORS PROFILE

Mr. J A Bellen pursed B.S. and M.Ed. in VSU, 2006 and 2010 respectively and is currently pursuing Ed.D. Science Education from CNU, Cebu City. He is working as Instructor in Department of Teacher Education from VSU since 2013. He has published research papers in reputed international journals. His interest is on environmental conservation and science education.

S.K.L. Sta. Maria, P.M.C. Winterstien and F.A.L. Chavez interest is on environmental conservation.

Mr. J A Bellen pursued B.S. in Agricultural Engineering from Visayas State University and is currently pursuing M.S. in University of the Philippines focusing on modelling salt water intrusion. His interest is on environmental conservation.

