VOL. 16, NO. 13, JULY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

OPTIMIZATION OF ROTARY COMPOSTING PROCESS IN INDONESIAN TROPICAL CLIMATE FOR HOUSEHOLD SOLID WASTE RECYCLING

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ABSTRACT

This research aims to find a best operating condition of a communal composter to process household solid waste to compost. 3 communal composters with a volume of 150 L and a diameter of 50 cm were used in this study. The composters have different operations including variation A with standard aeration and no stirring, variation B with standard aeration and stirring, and variation C with standard aeration, stirring, and blower for excess aeration. The compost activator used is Effective Microorganism (EM4), which is widely available in local market. Compost observations of 19-27 days resulting in temperature, pH, texture, colour, and odours complied with The Indonesian National Standard (SNI 19-7030-2004). Analysis on compost quality suggests that moisture content, C-organic, nitrogen, C/N ratio, phosphorus, and potassium meet the SNI 19-7030-2004. The composting process results in a reduction weight of around 48-51%. Scoring analysis suggests that composter with variation C displays the best performance on maturity, quality, and quantity.

Keyword: communal composter, household solid waste, composter treatment, stirring, blower, scoring.

1. INTRODUCTION

Solid waste is the solid residue of daily human activities or natural processes [1]. Commonly, the practice of solid waste management in Indonesia uses the collect-transport-dispose paradigm. As this paradigm, Indonesian cities prefer to terminate the cycle of solid waste by disposing to landfill (TPA). Unfortunately, as the cities provide less effort to manage the landfill area, it released a common landfilling failure issue. Indonesian cities expected that the existing landfill could solve solid waste management issues without pay proportional attention to this instrument [2].

Waste composition in Indonesia is dominated by biodegradable organic waste, which is around 60% by weight. Two primary waste types that are described as biodegradable organic waste are food waste and yard waste. In several Indonesian regions, including North Sumatera, South Sumatera, Riau, Jakarta, and East Java, the percentage of food waste is around 47.23% - 54.62%, and yard waste is around 4.12% - 9.02% [3]. The high composition of biodegradable organic waste in Padang City is about 67.68% food waste and 6.34% yard waste [4]. Effective water content for composting is usually around 50-60%, and the effective C/N ratio of compost raw material is 25-30 [2]. Based on the characteristics test, organic waste's average water content is 54.02% [5], and the C/N ratio is 30.25 [6]. Biological characteristics showed that the value of domestic waste biodegradability higher than any other source in 58.02% of the weight. Because of Indonesian Tropical Climate, domestic solid waste is quickly degraded. It attracts a high population of flies infesting domestic solid waste, and increases in odours, especially yard waste and food waste every day [7]. Since organic waste can release methane in the anaerobic type of Indonesian landfill, it will affect global warming and climate crisis. Waste generation is the second biggest cause of climate change after deforestation [8]. In Bandung City, methane emission from waste generation is 2,665.02 tons/year, and it is estimated to increase in the following years [9]. One of the appropriate measures to be developed in reducing domestic organic waste in Indonesia is by composting.

As a tropical climate country, Indonesia has a warm temperature to rapid degradation process of organic waste [10], typically food waste [11]. It supports the composting process as the appropriate technology and method to be applied on a household scale (as the largest contributor of organic waste) because of the suitability and convenient application [12]. On the contrary, anaerobic digestion requires a high operation and maintenance ability and has technical barriers, including leakage of methane gases and accumulation of solid subtract (sludge) [13]. While incineration technology requires high investment and has any pros and cons of its pollution [14].

Since the traditional composting method may take significant time, technological advances can accelerate the process, for instance, by adding additive materials called composting activator [15]. Previous research by Rahman [16] used bulking agents for best composition that consist of 50% sawdust, 20% rice husk ash, 25% bran, and 5% dolomite and the stardec as best activators. Under controlled active aeration (rotary) composter as the composting technology gives some advantages to household, including odour minimization due to air holes, equally stirring, convenient application, less effort needed in operation, and aesthetically maintained [17]. This technology only takes 19 days of composting time, 2-3 weeks faster than other [18]. All the advantages already mentioned are trying to be complied in this research.

This research aims to find a best operating condition of a communal composter to process household waste to compost. Indonesian National Standard (SNI 19-7030-2004) was used to assess compost maturity, quality, and quantity. To take advantage of local climate condition, the composters were set to different operating set ups. The

VOL. 16, NO. 13, JULY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

composter is designed with due observance of a perfect aeration system by considering air circulation's adequacy to supply oxygen needs for microorganisms in organic waste decomposition [19]. A household composter is a particular composter to process kitchen waste into compost. Based on the capacity, the household composter is divided into two types, including individual composter and communal composter. Individual composter accommodates one household, while communal composter accommodates the community of households [19].

2. METHODOLOGY

2.1 Design Principle of Communal Composter

As a tropical climate, Indonesia has a warm temperature that causes decomposition to carry out rapidly, results in bad odour and flies' presence. The two disturbances are very disliked by the households. The rotary composter's design principle in this research considers this condition by comprising two main system combinations: aerated composting and rotary drum composting. Aerated composting applies an active aeration system, which is more appropriate to household organic waste since the odour and flies presence are relatively less [20]. Meanwhile, rotary drum composting ensure a complete mixing thus take a short of composting time to process organic waste, about 19 days only compared to some regular composting systems [18]. The combination of active aeration and rotary drum composting (the complete-mix reactor) assured to be efficient, eco-friendly, low-cost, a small area required, high volume reduction (65% - 70%), effortless operation and maintenance, and flies-free for household solid waste management [21].

The communal composters with a volume of 150 L and a diameter of 50 cm were used in this study. The composter was equipped with a blower, vent, and air holes. Blower performed the addition of oxygen to the composter, vent automatically stream the air to the composter, and air holes adjust the composter's temperature. The stirring system was carried out manually by rotating the composter. The design layout of the composter is shown in Figure-1, and the manufactured composter is shown in Figure-2. Composter's set up was divided into three variations including variation A with standard aeration and no stirring, variation B with standard aeration and stirring, and variation C with standard aeration, stirring, and blower for excess aeration.

2.2 Material Preparation

This research prepared two primary materials, including raw composting materials and additive materials. The raw composting materials were defined as biodegradable (organic) waste composition like household waste composition. The additive materials comprised of activator and bulking agents. The type of bio-activator used in this research was effective microorganisms 4 (EM4), first discovered by Prof. Teruo Higa from Ryukyus University Japan. It is very popular in Indonesia due to the low-cost and user friendly. EM4 consists of about 80 fermenter microbials to accelerate organic matter decomposition [22]. Related microbials, including Lactobacillus sp, lactic acid-producing bacteria, photosynthetic bacteria, Streptomyces, and yeast, perform the decomposition process's synergy. While, bulking agent composition of previous research by Rahman [16] was used in this research. Table-1 displays composition set up of the three variations.

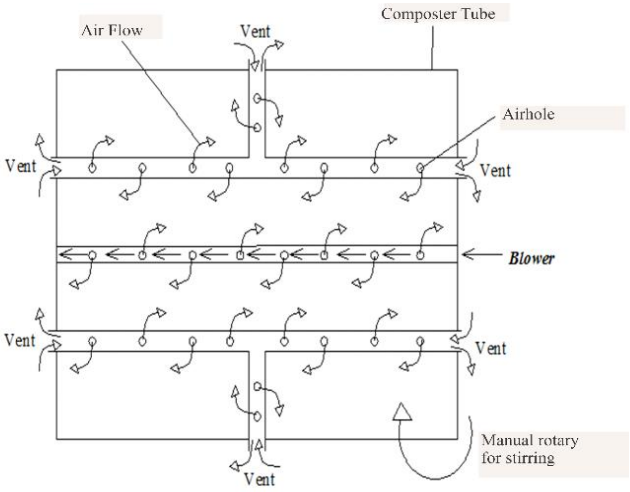

Figure-1. Composter's layout.

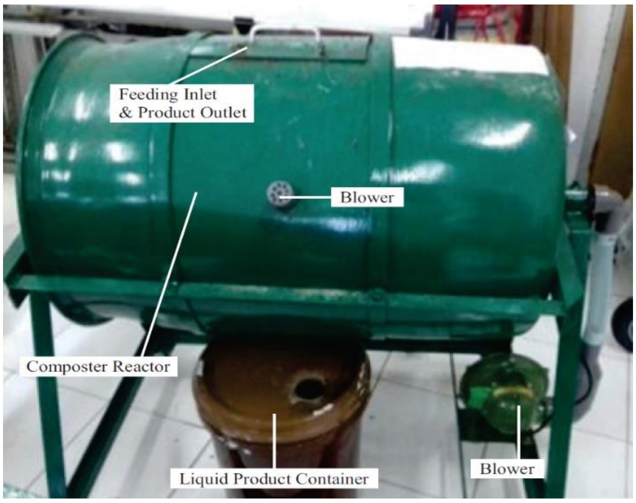

Figure-2. The manufacture composter.

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Table-1. Mixture composition of composting material for each variation.

No	Part	Mixture composition		
		Variation A	Variation B	Variation C
1	**Household waste**			
	Vegetable	16.28 kg	16.28 kg	16.28 kg
	Fruit	8.55 kg	8.55 kg	8.55 kg
	Rice	3.52 kg	3.52 kg	3.52 kg
	Side Dish	1.58 kg	1.58 kg	1.58 kg
	Yard	3.16 kg	3.16 kg	3.16 kg
2	Bulking agents			
	Sawdust	0.25 kg	0.25 kg	0.25 kg
	Rice Husk Ash	0.1 kg	0.10 kg	0.10 kg
	Bran	0.13 kg	0.13 kg	0.13 kg
	Dolomite	0.03 kg	0.03 kg	0.03 kg
3	Activator (EM_4)	33.09 mL	33.09 mL	33.09 mL
	Mixture of EM4 and water	1.60 L	1.60 L	1.60 L

2.3 Compost Analysis

The standard composting process was applied, including weigh and crush the raw materials, mix with the additive materials, and carried out the composter operations set up. Stirring was performed by rotating the composter in the morning, afternoon, and noon, and an additional blower was carried out during the stirring process. Mature compost was dried naturally outside the composter before crushing once again and sieving.

The compost maturity test was performed every three times a day, including in the morning, afternoon, and evening. The parameters being tested were temperature, moisture, texture and color, odor, and pH. Measurement of the compost quantity was conducted after harvesting the compost by calculating the harvested compost's weight and volume. Compost was obtained by sieving with the mesh sieve of 5 mm. The sieved compost was weighed and tested in the laboratory as a compost quality test. The compost quality parameters were moisture, C-Organic using Walkey Black method, Nitrogen using Titrimetry method, C/N ratio, phosphorus using Spectrofotometry method, and potassium using Atomic Absorption Spectrophotometry (AAS) method. The compost analysis must comply with SNI 19-7030-2004.

A simple scoring method was employed for comparing the composters. The scoring method gives a score for each of the variations based on the parameters. The criteria of the Scoring are shown below [16]:

- **Criteria 1:** a score of 1 is given if the variation meets the standard of SNI 19-7030-2004. The parameters of this criterion are to determine the compost quality.
- **Criteria 2:** a score of 0 is given to the variation that does not meet the quality standard of SNI 19-7030-2004. The parameters of this criterion are to determine the compost quality.
- **Criteria 3:** If parameters do not have a quality standard of SNI 19-7030-2004, Scoring is carried out based on the ranking. The maximum score is given to the best-scored variation, while the minimum score is given to the imperfect variations. Minimum Scoring is carried out from a score of 1. The parameters of this criterion are to determine the length of compost maturity time and compost quantity.

3. RESULT AND DISCUSSIONS

3.1 Compost Maturity

Figure-3 displays the daily temperature fluctuation for each variation. Temperature is a critical indicator in determining the maturity of compost. The initial composting process occurred in the mesophilic phase at the temperature of 18 - 22 ^{o}C [23]. The highest temperature was in variation C of 48^{o}C, while variation A was the lowest one, 45^{o}C. The thermophilic phase occurred at the temperature above 40^{o}C [23]. The highest temperature of variation C was caused by the oxygen provision by active aeration and the microbial's oxygen consumption that affect the increase in temperature [24]. After reaching the maximum condition, the temperature will slowly decrease to approach the soil temperature.

The composting process causes a transformation in organic matter and pH of the materials. As depicted in Figure-4, the final pH of composting for each variation has the same value of 7. It is following the criteria between 6, 80 - 7, 49 [25]. Variation C is approaching neutral pH faster than the variation A and B due to the sufficient oxygen supply. The availability of sufficient oxygen can contribute to ammonia and carbon dioxide production of organic matter decomposition, automatically increasing the pH value [26].

VOL. 16, NO. 13, JULY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

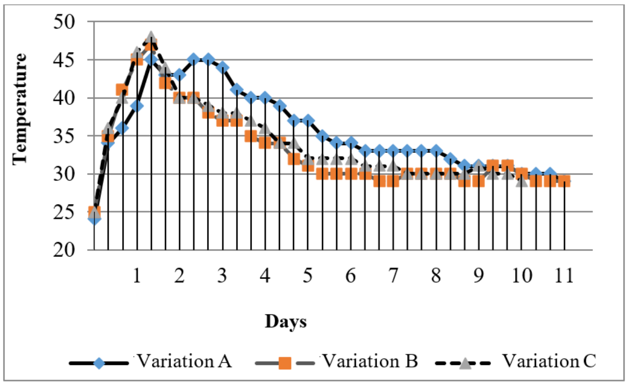

Figure-3. Monitoring of compost temperature.

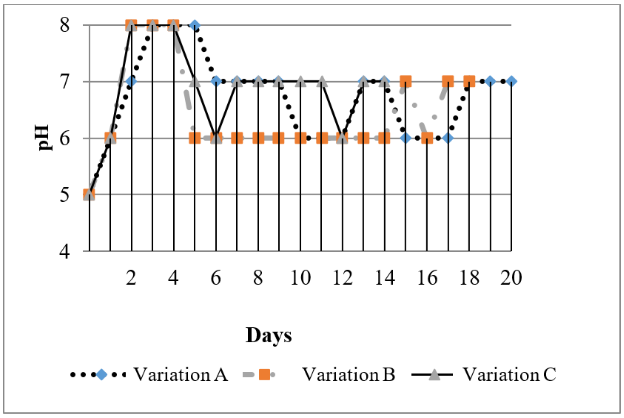

Figure-4. Monitoring compost pH.

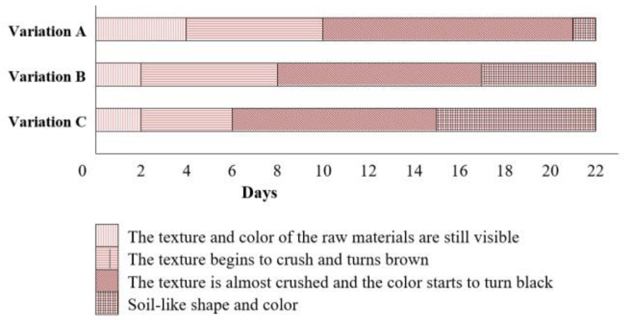

Figure-5. Monitoring compost texture and color.

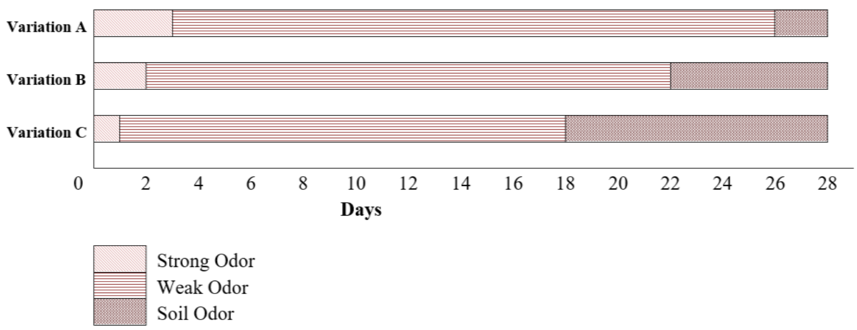

Figure-6. Compost odor monitoring.

During the initial composting process, the raw materials were in brownish-green color and rough texture, particularly for the yard waste. Variation C had rapidly transformed the shape and the color of compost as the soil at 19 days due to the mixing process and the blower that promotes a proper aeration process and spread the decomposition microbial evenly. The structure and color monitoring is shown in Figure-4.

Each variation releases the pungent odour of the food waste, particularly vegetable waste, during the initial composting process. The pungent odour declines from day 2 to day 4. All variations release soil odour in a row on days 27, 23, and 19. Variation B and C release the odour of soil faster than variation A due to the stirring process and active aeration. Thus, it maintains the aerobic condition and removes the strong odour slowly to the odour of soil. Monitoring the compost's odor is shown in Figure-6, and the entire compost maturity time results are in Table-2. It suggests that all variations took composting time in the range of 19-27 days. It is relatively faster than windrow composting that takes composting time in the range of 3-4 months until completely mature [2] and bin composting that needs two months [17].

3.2 Compost Quantity

The quantity of compost and percentage of reduction is displayed in Table-3. The solid compost quantity of variation C was relatively higher due to the stirring process and active aeration performed, so decomposition carried out was more optimum. The percentage of compost reduction rate for the three variations was 48-51% by the weight.

3.3 Compost Quality

The macro elements of solid compost for all variations had complied with all standards of SNI 19-7030-2004 about Compost Specifications of Domestic Organic Waste. Table-4 shows the results of the compost quality test. The low water content in variation C was due to stirring, leading to moisture evaporation outside the system. The presence of air flow from the blower resulted in easy evaporation of moisture out of the system. Another study showed that the more aeration to the compost, the lower the compost's moisture content [27]. The C/N ratio of soil is 10-12, and it is necessary to have the C/N ratio of compost close to the C/N ratio of soil [2].

Table-2. Results of compost maturity time.

Research Variations	Temperature (day)	pH (day)	Texture & Color (day)	Smell (day)	Composting Time (day)	Summary
Variation A	11	20	22	27	27	Slow
Variation B	11	18	18	23	23	Moderate
Variation C	10	14	16	19	19	Rapid

Table-3. Results of compost quantity test.

Research Variations	Initial Weight (kg)	Final Solid Compost (kg)	Solid Compost Reduction (%)
Variation A		15	48
Variation B	33.59	15.4	50
Variation C		16	51

Table-4. Results of solid compost quality test.

Research Variations	Water Content (<50%)	C-Organic (9,8-32)	Nitrogen (>0,4%)	Phosphorus (>0,1%)	Potassium (>0,2%)	C/N (10-20)
Variation A	46.33	17.59	0.94	2.40	2.12	18.71
Variation B	43.46	13.13	0.98	3.87	5.13	13.40
Variation C	41.44	11.14	1.03	5.83	5.98	10.82

Table-5. Scoring results of compost maturity.

Research Variations	Composting Time	Amount
Variation A	1	1
Variation B	2	2
Variation C	3	3

Table-6. Scoring results of compost quality.

Research Variations	Water Content	C-Organic	Nitrogen	C/N	Potassium	Phosphorus	Amount
Quality Standard	< 50%	9,8-32%	(> 0,4%	(10-20)	>0,2%	>0,1%	
Variation A	1	1	1	1	1	1	6
Variation B	1	1	1	1	1	1	6
Variation C	1	1	1	1	1	1	6

Table-7. Scoring results of compost quantity.

Research Variations	Solid Compost	Amount
Variation A	1	1
Variation B	2	2
Variation C	3	3

Table-8. Recapitulation of total compost scoring.

Parameter	Variation A	Variation B	Variation C
Compost Maturity	1	2	3
Compost Quality	6	6	6
Compost Quantity	1	2	3
Amount	8	10	12

Variation C had the percentage of C-Organic and Nitrogen close to the C/N ratio of soil, namely 10.82. It means variation C is the most applicable to use immediately. The compound of phosphor and potassium in all variations complied with the criteria, with variation C had a high percentage of the two parameters. The phosphorus source in the soil is quite a lot. However, plants can still experience a phosphorus deficiency due to most phosphorus chemically bound by other elements. It becomes a difficult compound to dissolve in water [28]. The phosphorus content in the compost can comply with soil and plants needed when applied. The presence of potassium in compost can increase the cation exchange capacity, related to negative charges. This negative charge is the potential for humus to adsorb cations such as Ca, Mg, and K, which are bonded with moderate strength, so they are easily exchanged or undergo a cation exchange process [28].

3.4 Scoring Results

The scoring analysis considers the three tests, including compost maturity (time), compost quality, and compost quantity. These scoring results are shown in Table-6 to Table-9.

Based on Criteria 3, variation C gains a score of 3 in the maturity test (Table-6) due to the short time of composting, precisely 19 days. Based on Criteria 1 and 2, all parameters of each variation get a score of 1 in the quality test (Table-7) since they comply with all standards of SNI 19-7030-2004. Variation C obtains the highest score of 3 due to the highest compost quantity (Table-8) than the other variations based on Criteria 3. As a result of combining the variations score, variation C has the highest score of 12 (Table-9), while variation A and B successively score 8 and 10.

4. CONCLUSIONS

The rotary composter of 150 L was designed with a blower, air holes, and manual stirring to optimize the local tropical condition. Compost maturity was achieved in the range of 19 - 27 days by observing maturity parameters, including temperature, pH, texture, colour, and odours, and comparing with Indonesian National Standard (SNI) 19-7030-2004. Compost quality, including moisture, C-Organic, Nitrogen, C/N ratio, phosphorus, and potassium, also complied with SNI 19-7030-2004. Quantity of solid compost result was in the range of 15-16 kg by the initial weight of 33.59 kg, so the compost reduction was 48-51% by weight. Operating condition with excess aeration and stirring displayed a best condition for processing household solid waste to compost.

ACKNOWLEDGEMENTS

This work was supported by the Faculty of Engineering, Andalas University, under Grant No. 023/UN.16.09.D/PL/2020

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