Reaktor

p-ISSN 0852 – 0798
e-ISSN 2407 – 5973

Acredited: SK No.: 60/E/KPT/2016
Website : http://ejournal.undip.ac.id/index.php/reaktor/

Reaktor, Vol. 18 No. 4, December Year 2018, pp. 194-201

Assessment of Compost Maturity using The Static Respirometry Index

Gabriel Andari Kristanto*) and Syifa Aulia Rahmah

Environmental Engineering Program, Civil Engineering Department, Universitas Indonesia
Kampus Universitas Indonesia
Jl. Margonda Raya, Depok 16424

*) Corresponding author: andari@eng.ui.ac.id

(Received: October 10, 2018 Accepted: December 15, 2018)

Abstract

To be used as organic fertilizer, compost must be stable and mature enough to ensure that it is safe for agricultural application. The stability and maturity of compost can be viewed from physical, chemical, and biological parameters. One of the biological parameters is the static respiration index (SRI). In many places, the SRI is applied as a representative indicator of the stability and maturity of compost but not in Indonesia compost standard of the SNI 19-7030-2004. This study aims to assess the index of the static respiration of composts and analyze their stability and maturity. The assessment was carried out on 10 compost samples sold in Jakarta and Depok. It is observed that 8 of 10 tested composts was stable and mature, with a static respiration index of 0.61–1.35 mg O_2 g^{-1} VS h^{-1}. One of the 10 composts was very stable and very mature, with a static respiration index of 0.46 mg O_2 g^{-1} VS h^{-1} and 1 compost was unstable and immature, with an index of 1.79 mg O_2 g^{-1} VS h^{-1}. The results indicated that re-composted for seven days was adequate to make the compost more stable and mature than the initial state. Since maturity is not described by a single property, it is great assurance for the compost producer and end user in Indonesia that not only physical and chemical characteristics are used as indicator for compost stability and maturity but also biological indicator such as SRI.

Keywords: *compost; maturity; stability; static respiration index*

How to Cite This Article: Kristanto, G.A. and Rahmah, S.A. (2018), Assessment of Compost Maturity using The Static Respirometry Index, Reaktor, 18(4), 194-201, http://dx.doi.org/10.14710/reaktor.18.04.194-201.

INTRODUCTION

High generation of wastes in Indonesia become a serious challenge since integrated solid waste management has not been implemented. Ninety percent of districts/cities in Indonesia are mostly conducted open dumping and open burning to manage their wastes. In 2014, it is reported that the volume of waste in Indonesia was around 64 million tons/year; among them, 69% of waste was dumped in the landfill, 10% was buried, 5% was burned, and only 7.5% was used as compost and recycled, and the rest was not managed (KLHK, 2017). Previous study mentioned that these problems can be addressed by implementing integrated solid waste management through the selection of waste treatment technologies such as composting (Tchobanoglous & Kreith, 2002). Composting is an effective technique that could be applied to manage organic waste from urban areas since it can reduce the volume of organic waste by up to 50% and the final product can be used as agricultural applications, adsorbent, land reclamation, etc. (Tchobanoglous & Kreith, 2002; Levis et al., 2010, Kristanto, et al., 2015; Kristanto et al., 2017).

An important criterion to ensure the quality of compost for agriculture application is that compost must be stable, mature, and not contain phototoxic compounds (Barrena et al., 2014; Oviedo et al., 2015). Compost stability illustrates the amount of organic matter that has decomposed (Lasaridi & Stentiford, 1998). Meanwhile, maturity describes the ability of the compost to be used effectively in agriculture and related to plant growth and not contain phytotoxicity (Oviedo et al., 2015). Moreover, the stability and maturity of compost is important since they related to the safety of the use of compost. The unstable and immature compost will hinder plant growth and negatively impact soil quality (Cesaro et al., 2015; Riffaldi et al., 1986; Wu et al., 2000; Tang et al., 2003).

Previous studies mentioned that the stability and maturity of compost can be reviewed from physical and chemical parameters, such as the Carbon/Nitrogen (C/N) ratio and respirometry methods. However, the C/N ratio is not a reliable indicator of stability because of the large variability in the value of the C/N ratio (Komilis & Kletsas, 2012).

There are two main respirometry methods for measuring compost stability: the dynamic (DRI) and the static respiration Indices (SRI), These two methods depend on whether oxygen absorption is carried out in the absence (static) or presence of oxygen (dynamic) during continuous biomass aeration (Scaglia et al., 2000). It is found that the DRI and SRI values had almost the same magnitude (Adani et al., 2000). In the first 10 days during composting, it is shown that the DRI and SRI increase initially but then decrease with increasing composting time. The reducing of DRI and SRI indicate that the compost become more stable. It is known that the DRI tend to be higher than the SRI because of the continuous air flow in a dynamic system support the transport of oxygen to biomass (Scaglia et al, 2000).

Static respirometry techniques can be carried out by measuring both CO_2 production and O_2 consumption (Kuter et al., 1985; Atkinson et al., 1996; Pe'rez et al., 1999; Larsen and McCartney, 2000; Lasaridi et al., 2000). However, the measurement of oxygen (O_2) consumption is more often used in laboratory-scale research because its measurement is more representative of aerobic biological processes (Barrena et al., 2009). Since then, the SRI is used as a control indicator for compost stability monitoring of the composting process and estimating the maturity of a material (Sullivan & Miller, 2001; Tchobanoglous & Kreith, 2002; Barrena et al., 2006).

Several countries and even state especially in the US have identified the importance of SRI standard on compost quality. For example, the United States sets the SRI standard less than 3 mg O_2 g^{-1} OM d^{-1} (US Department of Agriculture & US Composting Council, 2001), in California, it is less than 0.5 mg O_2 g^{-1} OM d^{-1} (US Department of Agriculture & US Composting Council, 2001), and in Canada, it is 400 mg O_2 kg^{-1} VS h^{-1} (Canadian Council of Ministers of the Environment CCME, 2005).

Unfortunately, SRI has not been used as an indicator of the stability and maturity of compost in Indonesia. While compost quality standards in Indonesia refer to SNI 19-7030-2004, the compost stability and maturity are only indicated from physical and chemical parameters. The objectives of this study is to assess the stability and maturity of compost available in the Indonesia market based on the SRI values. Based on those baseline data, the recomposted is conducted for increasing maturity and stability of compost, hence additional time can be analyzed until the compost reach its maturity.

RESEARCH METHODS

Ten composts sold in the Jakarta and Depok were chosen as samples (A, B, C…J). The physical and chemical parameters, such as color, water content, volatile solids (VS), and the C/N ratio, were examined to determine their initial characteristics. The water content was measured by the gravimetric method in which sample was dried at 105 ℃ for 3 hours. The different weight of samples before and after the drying process is the water content in the compost. The VS was measured using the loss-on-ignition (LOI) method, in which the sample was burned at temperature of 550℃) for 1 hour. The different weight of samples before and after the burning process is the VS. The total C was measured with Walkey and Black methods. The total N was examined using the Total Kjeldahl Nitrogen (TKN) method DR 5000 spectrophotometer (Hach, Inc.).

To analyze the SRI, a modification of method developed by Lasaridi and Stentiford's were performed (1998). Firstly, compost was converted into suspension by mixing 15 grams of compost with 500 mL of distilled water. The mixture was placed in a 1000 mL Erlenmeyer and then nutrients and aeration were conducted every 15 minutes for 45 minutes and continued with the incubation for 18 hours; 15 mL of phosphate buffer (without NH_4Cl, to inhibit the formation of nitrogenous oxygen demand and 5 mL of $CaCl_2$, $FeCl_3$, and $MgSO_4$ were added. The nutritional solutions are made according to the standard method of the Biological Oxygen Demand (BOD) test procedures based on SNI 6989.72: 2009.

After incubation, sample was aerated again for 20 minutes, and placed in the water bath at 37℃ and then analyzed for DO (Dissolved Oxygen). During aeration and testing, the Erlenmeyer was sealed to minimize oxygen diffusion. The DO measurements were carried out every 1 minute for 2 hours for each sample. using DO meters connected to the data logger. The DO performed in duplicate.

The DO was expressed in mg O_2 L^{-1}. The SRI value was calculated with the equation below:

$$SRI\ (mgO_2 g^{-1} VS\ h^{-1}) = \frac{V\ x\ P\ x\ 31{,}98\ x\ s\ x\ 60}{R\ x\ T\ x\ X\ x\ DM\ x\ OM} \qquad (1)$$

Where V is the volume of air in the flask, in mL units; P is the atmospheric pressure in the atm unit; 31.98 is the molecular weight of oxygen gas; 60 is a conversion factor from minute to hour; s is the slope of the oxygen drop during respiration test in the percentage of O_2 per minute divided by 100 (mol O_2 mol^{-1} min^{-1}), where the slope was obtained from the graph as the percentage of oxygen saturation to the measurement time; R is the ideal gas constant = 0.08206 (L atm mol^{-1} K^{-1}); T is the temperature at measurement, which is 310 K; X is the wet weight of the compost sample, which is 15 grams; DM is the total fraction of solids from compost samples (g DM g X^{-1}), and OM is the fraction of organic matter from compost samples in dry weight (g OM g DM^{-1}).

Based on the result of the SRI, some of the compost samples were recomposted using Takakura method until the SRI showed that the compost was more mature and stable. The length of the days needed for those composts to reach the maturity and stability are recorded and analyzed. The scanning electron microscope investigation was also conducted to analyze the morphology of compost before and after the recomposting.

RESULTS AND DISCUSSION

Initial Physical and Chemical Characteristic of Compost

In this present study, the physical and chemical quality of compost were compared with SNI 19-7030-2004. Since no standard available for compost stability and maturity in Indonesia, the SRI result was compared with the CCQC standard. The initial compost characteristics are presented in Table 1.

It is found that all 10 composts have dark brown to black color and smell like soil hence met Indonesia standard of SNI 19-7030-2004. In addition, 9 compost products have a water content more than 50% which is higher than the standard of SNI 19-7030-2004. High humidity of compost (more than 80%) will create anaerobic conditions hence impacting the compost quality (Azim et al., 2017). On the other hand, Sullivan and Miller (2001) mentioned that the water content of compost must not be less than 35% since it indicated instability, drive the rapid dehydration of compost, cause the cessation of biological processes, and produce physically stable but not biologically stable compost (Bertoldi et al. (1983). In this present study, it is found that with low moisture content, compost J has a high dry matter percentage of 85.99%. This is consistent with Sullivan and Miller (2001) that if the percentage of moisture content increases, the dry matter of the total weight of compost will decrease.

According to SNI 19-7030-2004, the VS standard is 27–58% and the results of this study show that 50% of compost have VS values that meet the standards. The SNI 19-7030-2004 also recommends standard of C/N ratio of 10–20: Three samples have a C/N ratio of less than 10. Tchobanoglous & Kreith (2002) mentioned that a C/N ratio with a value less than 15 or 20 can cause a loss of nitrogen in the form of ammonium nitrate. Moreover, Roman et al. (2015) also mentioned that a low C/N ratio indicates an incomplete composting process in which the material has not reached its mature state and could cause phototoxicity (Azim, et al., 2017). Compost with a C/N ratio value of more than 20/1 are samples D and E, with a C/N ratio of 27.83 and 31.76, respectively. A C/N ratio higher than 20/1 or 30/1 could delay the composting process (Tchobanoglous & Kreith, 2002). Material with high C/N ratio can lead a biological block of nitrogen, also known as "nitrogen starvation". This condition occurs in composting raw materials that have a higher C content than N content (Azim et al., 2017). According to Roman et al (2015), the similar compost when applied to the soil, cause microorganisms to quickly take the C present in the material, hence increase the consumption of N and cause reserved N to run out (Azim et al., 2017).

Table 1. Initial Characteristics of Compost

Compost	**Color**	**WC (% w/w)**	**(WC <50%)**	**DM (%)**	**VS (% dry weight)**	**(VS 27%-58%)**	**C/N**	**(C/N 10-20)**
A	Dark Brown	56.94	x	43.06	23.93	x	12.28	√
B	Black	56.60	x	43.40	29.75	√	11.54	√
C	Dark Brown	66.47	x	33.53	15.04	x	3.9.6	x
D	Dark Brown	56.86	x	43.14	39.41	√	27.83	x
E	Dark Brown	55.60	x	44.40	33.20	√	31.76	x
F	Dark Brown	56.57	x	43.43	29.76	√	10.04	√
G	Dark Brown	70.16	x	29.84	23.65	x	19.36	√
H	Dark Brown	63.49	x	36.51	15.28	x	7.54	x
I	Blckish Brown	67.76	x	32.24	19.51	x	11.22	√
J	Black	14.01	√	85.99	41.07	√	16.33	√

Remark:
WC: Water Content; DM (Dry Matter); VS (Volatile Solid); C/N (Carbon/Nitrogen) Ratio
√: Fulfill SNI 19-7030-2004;
x: Does not fulfill SNI 19-7030-2004

SRI Assessment

Figures 1 and 2 shows the average decrease in saturated oxygen with time in composts produced in Depok and Jakarta.

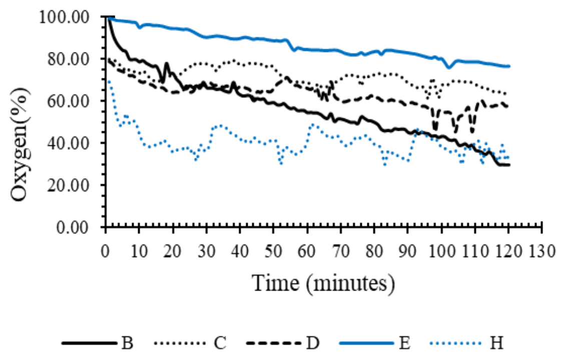


Figure 1. Decrease in Saturated Oxygen Percentage in the Compost Product in Jakarta

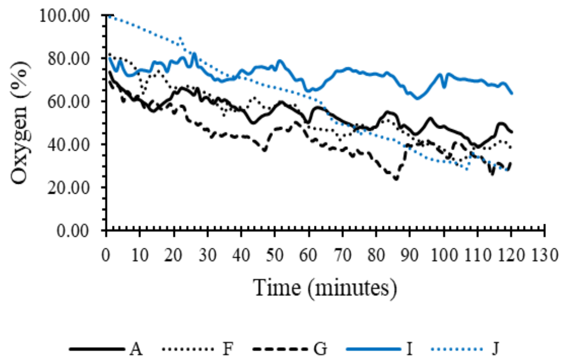


Figure 2. Decrease in Saturated Oxygen Percentage in the Compost Product in Depok

All composts showed a decrease in the percentage of saturated oxygen during 120 minutes' analysis and a significant reduction of oxygen from the beginning to the end of the oxygen measurement will determine the level of stability of each compost. From figures 1 and 2, two slopes are obtained, and the SRI was calculated using eq. 1. The initial SRIs of all composts are presented in the Table 2.

Since Indonesia do not have SRI standard, the result of this current study is compared to the CCQC standard. It is found that the SRI value of compost G is 1.79 mg O_2 g^{-1} VS h^{-1} which means unstable and immature. Eight other compost products are stable and mature, with SRI values in the range of 0.61–1.35 mg O_2 g^{-1} VS h^{-1}. The most stable and mature compost is Compost D with an SRI value less than 0.5 mg O_2 g^{-1} VS h^{-1}, which is 0.49 mg O_2 g^{-1} VS h^{-1}.

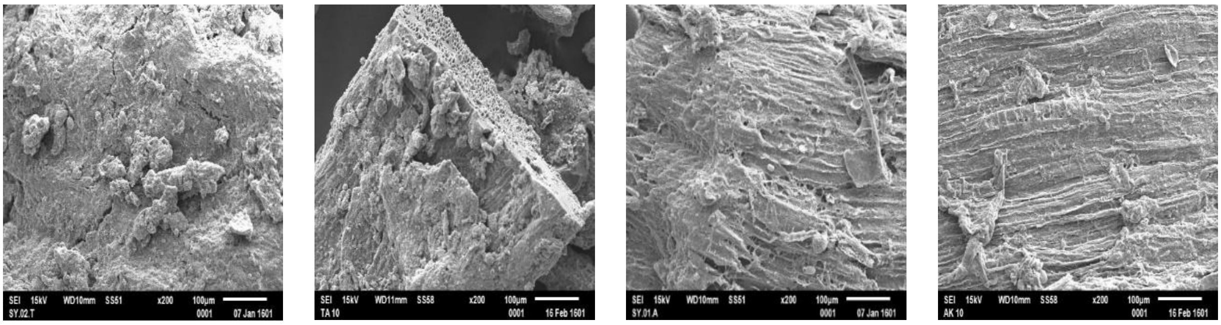
Compost Characteristics Before and After Composting

Before and after recomposted of compost A, B, F, and G characteristics are presented in table 2 and figure 3. The Takakura Method is applied during recomposted since it is easy to use and can be conducted in a small-scale system (Japan International Cooperation Agency (JICA), n.d.; Kurniawan, 2014; Wakamatsu Environment Research Institute, 2009). Figure 3 only presents the results of SEM of samples B and G since all four samples indicating similar condition. In all samples, the particle size of compost was larger and less porous before recomposted. The compost particles are more properly arranged after recomposted than before since lignin structure change from columnar or massive to lamellar or mesh-like, when the lignin structure become porous and flocculent structure, it can be considered that compost finished.

Table 2. Initial SRI Value and Assessment of The Stability and Maturity of The Compost

Compost	**SRI (mg O_2 g^{-1} VS h^{-1})**			*** Stability**	**** Maturity**	**Stability x Maturity**
	Flask 1	Flask 2	Average			
A	0.88	0.87	0.88	stable	mature	mature
B	1.21	1.06	1.14	stable	mature	mature
C	0.83	0.97	0.90	stable	mature	mature
D	0.49	0.43	0.46	very stable	very mature	very mature
E	0.63	0.60	0.61	stable	mature	very mature
F	1.24	1.46	1.35	stable	mature	mature
G	1.99	1.60	1.79	less stable	immature	immature
H	1.01	0.70	0.86	stable	mature	mature
I	0.74	0.52	0.63	stable	mature	mature
J	0.83	0.95	0.89	stable	mature	mature

Remarks:
Annotation: Stability and maturity standards according to CCQC
*Very Stable (<0.5 mg O_2 g^{-1} VS h^{-1}); Stable (0.5 – 1.5 mg O_2 g^{-1} VS h-1); Less Stable (>1.5 mg O_2 g-1 VS h^{-1})
** Very Mature (<0.5 mg O_2 g-1 VS h^{-1}); Mature (0.5 – 1.5 mg O_2 g-1 VS h-1); Immature (>1.5 mg O_2 g-1 VS h^{-1})



(a) (b) (c) (d)

Figure 3. SEM results (200x magnification) (a) Compost B Before Composting; (b) Compost B After Composting; (c) Compost G Before Composting; (d) Compost G After Composting

Table 3. The Chemical Characteristics of Composts A, B, F, G Before and After Composting

Compost	Day	WC	DM	VS	C/N Ratio
B	0	56.60%	43.40%	29.75%	11.54
			After Composting		
	7	45.62%	54.38%	31.89%	12.64
	10	47.21%	52.79%	34.52%	17.46
F	0	56.57%	43.43%	29.76%	10.04
			After Composting		
	3	51.39%	48.61%	32.46%	13,.8
	7	51.40%	48.60%	32.17%	13.33
	10	48.62%	51.38%	33.17%	12.98
A	0	56.94%	43.06%	23.93%	12.28
			After Composting		
	3	54.44%	45.56%	23.55%	14.05
	7	69.89%	30.11%	23.91%	12.84
	10	67.75%	32.25%	25.89%	22.67
G	0	70.16%	29.84%	23.65%	19.36
			After Composting		
	3	56.24%	43.76%	28.31%	45.06
	7	53.59%	46.41%	24.14%	11.56

Remark:
WC (Water Content); DM (Dry Matter); VS (Volatile Solids
Day 0: Compost characteristic before composting

During recomposted, the SRI values of the four compost samples were measured again on days 3, 7, and 10. Figure 4-7 shows a graph of the decrease of the percent oxygen saturation in the initial conditions (before composting) and after recomposted. The percentage of oxygen saturation continuously decrease during recomposted indicating the four compost become more stable and mature with increasing composting time. The SRI from the four compost samples on the 10th day were in the range of 0.5–1.5 mg O_2 g^{-1} VS h^{-1} (Figure 8). However even after 7 days of recomposted, it is enough to increase the stability and maturity of the compost.

During the experiment it is observed that the initial percentage of oxygen saturation (at t = 0) did not start at 100%, in some of the compost as shown Figures 1-2 and Figures 4-7. Iannotti et al., (1993) mentioned that it is possibly caused by oxygen diffusion during compost testing and different environmental conditions such as temperature and climate factors.

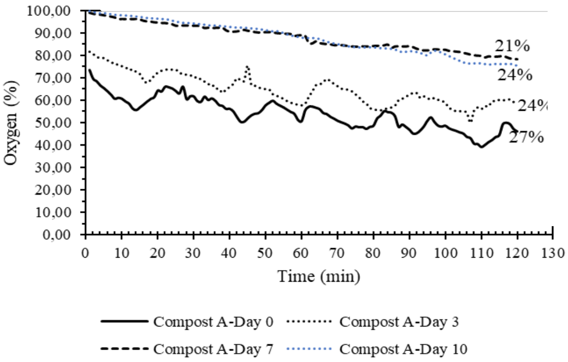


Figure 4. Oxygen Saturation Changes to Time in Compost A Samples in Initial Conditions, Day 3, and Day 7

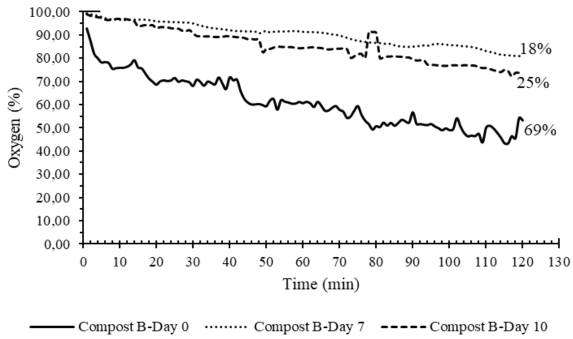


Figure 5. Oxygen Saturation Changes to Time on Compost B Samples in Initial Conditions, Day 7, and Day 10

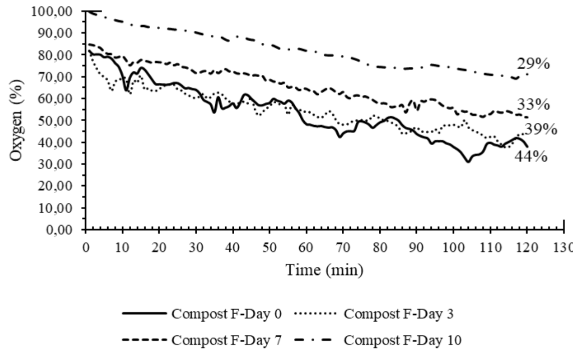


Figure 6. Oxygen Saturation Changes to Time on Compost F Samples in Initial Conditions, Day 3, Day 7, and Day 10

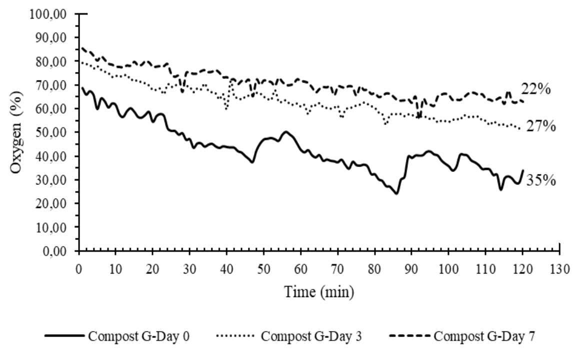


Figure 7. Oxygen Saturation Changes to Time on Compost G Samples in Initial Conditions, Day 3, and Day 7

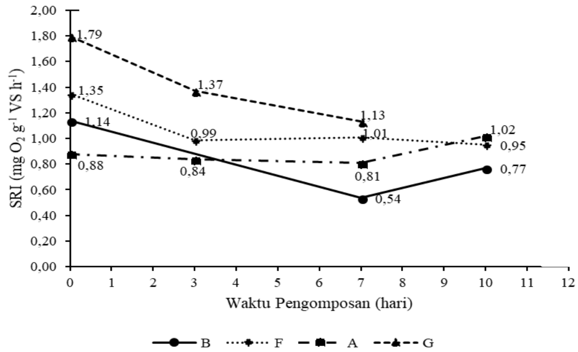


Figure 8. The SRI of Compost A, B, F and G After 7 Days of Recomposted

CONCLUSIONS

This study assessed the SRI as index of maturity and stability of compost available in the market in Indonesia. Ten different samples are analyzed their maturity and stability based on the physical and chemical characteristics and the SRI.

The results of stability and maturity of the compost based on the physical and chemical characteristics, as stated in SNI 19-7030-2004, are as follows: 10 compost were indicated to be mature; 9 out of 10 compost has enough water content while 1 compost has too low moisture content; 5 out of 10 compost meet the standard while 5 other compost does not meet VS standard; 6 out of 10 compost meet the standard of C/N ratio.

On the other hand, based on the SRI, degree of maturity and stability are varied among composts. It is found that 8 out of 10 composts have been in a stable and mature state, with SRI are within the range 0.61 - 1.35 mg O_2 g^{-1} VS h^{-1}. One compost was very stable and very mature with a SRI of 0.46 mg O_2 g^{-1} VS h^{-1}. One compost was less stable and immature (compost G) with SRI value of 1.79 mg O_2 g^{-1} VS h^{-1}. The results indicated that recomposted for seven days was adequate to increase stability and maturity of compost.

A mature compost should be considered to possess characteristics of completeness in the composting process and show minimal potential for negative impacts on plant development. Since maturity is not described by a single property, it is great assurance for the compost producer and end user in Indonesia that not only physical and chemical characteristics are used as indicator for compost stability and maturity but also biological indicator such as SRI.

ACKNOWLEDGEMENTS

The authors would express their gratitude for the financial support of the present work by Indonesia Higher Education Grant Scheme for the budget year 2019. We also thank the anonymous reviewers for their constructive comments.

REFERENCES

Adani, F., Lozzi, P., & Genevini, P. (2000). Determination of biological stability by oxygen uptake on municipal solid waste and derived products. *Compost Science*, 9, pp. 163-178.

Atkinson, C.F., Jones, D.D., Gauthier, J.J., (1996). Biodegradabilities and microbial activities during composting of municipal solid waste in bench-scale reactors. *Compost Science & Utilization*, 4, pp. 14–23.

Azim, K., Soudi, B., Boukhari, S., Perissol, C., Roussos, S., & Alami, I. T. (2017). Composting parameters and compost quality: a literature review. *Springer Science*, 8(2), pp. 141-158.

Barrena, R., d'Imporzano, G., Pons´a, S., Gea, T., Artola, A., V´azquez, F., Sanchez, Adani, a. F. (2009). In search of a reliable technique for the determination of the biological stability of the organic matter in the mechanical–biological treated waste. *Journal of Hazardous Materials*, 162, pp. 1065-1072.

Barrena, R., Font, X., Gabarrell, X., & Sánchez, A. (2014). Home composting versus industrial composting: Influence of composting system on compost quality with focus on compost stability. *Waste Management*, 34, pp. 1109-1116.

Barrena, R., Vázquez, F., & Sánchez, A. (2006). The Use of respiration Indices in the composting process: a review. *Waste Management & Research*, 24, pp. 37-47.

Cabañas-Vargas, D., Sánchez-Monedero, M., Urpilainen, S., Kamilaki, A., & Stentiford, E. (2005). Assessing the stability and maturity of compost at large-scale plants. *Ingenieria, 9*(2), 25-30.

California Compost Quality Council CCQC. (2001). *California Compost Quality Council. Compost Maturity, Index, Technical Report.* Nevada. Retrieved November 11, 2017, from http://www.ccqc.org

Canadian Council of Ministers of the Environment CCME. (2005). *Guideline for Compost Quality.* Winnipeg. Retrieved October 29, 2017, from www.ccme.ca

Cesaro, A., Belgiorno, V., & Guidab, M. (2015). Compost from organic solid waste: Quality assessment and Europeanregulations for its sustainable use. *Resources, Conservation and Recycling*, 94, pp. 72-79.

Chen, Y. (2003). Nuclear magnetic resonance, infra-red and pyrolysis studies of solid waste composts. *Compost Sci. Util.*, 11(2), pp. 152-168.

De Bertoldi M, Vallini G, Pera A (1983) The biology of composting: a review. *Waste Management Resources*, 1(1), pp 157–176.

Haug. (1993). *The Practical Handbook of Compost Engineering.* USA: Lewis Publisher.

Iannotti, D., Pang, T., B.L. Tothl, D. E., Keener, H., & Hoitink, a. H. (1993). A Quantitative respirometric method for monitoring compost stability. *Compost Science and Utilization*, 1, pp. 52-65.

Japan International Cooperation Agency (JICA). (n.d.). Retrieved April 9, 2018, from https://www.jica.go.jp/english/our_work/thematic_issues/management/study_takakura.html

Ministry of Environment and Forestry. (2017). Retrieved from http://www.menlh.go.id/rangkaian-hlh-2015-dialog-penanganan-sampah-plastik/

Komilis, D., & Kletsas, C. (2012). Static respiration indices to investigate compost stability: Effect of sample weight and temperature and comparison with dynamic respiration indices. *Bioresource Technology, 121*, pp. 467-470.

Kristanto, G.A, Raissa, S.M.; Novita, E. 2015. Effects of compost thickness and compaction on methane emissions in simulated landfills. The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5), *Procedia Engineering*, 125, pp. 173-178.

Kristanto, G.A., Lamurvie, A.R., Koven, W. 2017. A Study of Compost as an Adsorbent for Congo Red Dye Removal Process. *Reaktor*, Vol. 17 No. 4, pp. 203-209.

Kurniawan, T. (2014). The global environment and Japanese innovation: takakura home composting (THC) in Surabaya (Indonesia). *Japan Spotlight*, pp. 42 - 45.

Kuter, G., Hoitink, H., Rossman, L., (1985). Effects of aeration and temperature on composting of municipal sludge in a full-scale vessel system. *Journal Water Pollution Control Fed*, 57, pp. 309–315.

Larsen, K., McCartney, D., (2000). Effect of C:N ratio on microbial activity and N retention: bench-scale study using pulp and paper biosolids. *Compost Science & Utilization*, 8, pp. 147–159.

Lasaridi, K. E., & Stentiford, E. I. (1998). A Simple Respirometric Technique for Assessing Compost Stability. *Elsevier Science, 32*, pp. 3717-3723.

Lasaridi, K.E., Stentiford, E.I., Evans, T., (2000). Windrow composting of wastewater biosolids: process performance and product stability assessment. W*ater Resource*, 42, 217–226.

Levis, J., Barlaz, M., Themelis, N., & Ulloa, P. (2010). Assessment of the state of food waste treatment in the United States and Canada. *Waste Management, 30*, 1486-1494.

Oviedo, E., Torres-Lozada, P., Marmolejo-Rebellon, L., Hoyos, L., Gonzales, S., Barrena, R., Sanchez, A. (2015). Stability and maturity of biowaste composts derived by small municipilities : Correlation among physical, chemical and biological indices. *Waste Management, 44*, pp. 63-71.

Perez, C., Manzano, S., Soliva, M., (1999). Compostaje conjunto de la fraccio´n orga´nica de residuos municipales (FORM) y residuos vegetales: influencia sobre los desprendimientos de CO_2 y NH_3. *Residuos*, 46, pp. 44–51.

Riffaldi, R., Levi-Minzi, R., Pera, A., De Bertoldi, M., (1986). Evaluation of compost maturity by means of chemical and microbial analyses. *Waste Management Resources*, 4 (4), pp. 387–396.

Roman P, Martinez MM and Pantoja A (2015) Farmer's Compost Handbook: Experiences in Latin America. FAO Rome. ISBN: 978–92–5-107845-7. http://www.fao.org/3/a-i3388e.pdf

Scaglia, B., Tambone, F., Genevini, P. L., & Adani, F. (2000). Respiration index determination: dynamic and static approaches. *Compost Science & Utilization, 8*, pp. 90-98.

Sullivan, D. M., & Miller, R. O. (2001). Compost Quality Attributes, Measurements, and Variability. In *Compost Utilization in Horticultural Cropping Systems.* New York: Lewis Publishers.

Tang, J.C., Inoue, Y., Yasuta, T., Yoshida, S., Katayama, A., 2003. Chemical and microbial properties of various compost products. *Soil Science and Plant Nutrition*, 49 (2), pp. 273–280.

Tchobanoglous, G., & Kreith, F. (2002). *Hand Book Of Solid Waste Management Second Edition.* United States: The McGraw-Hill Companies.

US Department of Agriculture & US Composting Council. (2001). *Test methods for the examination of composting and compost.* Houston: Edaphos International.

Wakamatsu Environment Research Institute. (2009). https://kitakyushu.iges.or.jp/publication/Takakura/Takakura_Method_Full.pdf

Wu, L., Ma, L. Q., & Martinez, G. A. (2000). Comparison of Methods for Evaluating Stability and Maturity of Biosolids Compost. *Journal of Environmental Quality*, *29*, pp. 424-429.