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PERFORMANCE COMPARATION OF CO-COMPOSTING PROCESS OF BAGASSE AND FILTER CAKE ON 100 KG SCALE TO LABORATORY SCALE

PERBANDINGAN KINERJA PROSES CO-COMPOSTING BAGAS DAN BLOTONG PADA SKALA 100 KG TERHADAP SKALA LABORATORIUM

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ABSTRAK

Penelitian untuk menentukan kondisi optimum proses co-composting bagas dan blotong pada skala laboratorium telah dilakukan. Namun, untuk dapat diaplikasikan di industri perlu dilakukan evaluasi terhadap kinerja co-composting dengan membandingkannya pada skala yang lebih besar. Tujuan penelitian ini adalah membandingkan kinerja proses co-composting bagas dan blotong pada skala 100 kg dengan skala laboratorium. Parameter kinerja utama yang dievaluasi meliputi kinetika proses berupa laju pengomposan serta pengaruh aerasi terhadap laju penurunan C/N. Peningkatan skala co-composting dilakukan dengan memperbesar kapasitas produksi dari 5 kg (skala laboratorium) menjadi 100 kg. Faktor yang dipertahankan berupa kesamaan geometri reaktor, laju aerasi dan nilai C/N awal. Penelitian dilakukan selama 60 hari dengan nilai C/N awal sebesar 50 dan pemberian aerasi aktif sebesar 0,4 L/menit.kg bahan selama 1 jam perhari pada minggu pertama. Pengamatan proses pada skala 100 kg menunjukkan kondisi proses yang sama dengan skala laboratorium dengan pencapai suhu mesofilik, pH sekitar netral, kadar air optimum, dan peningkatan nitrat dimulai pada minggu kedua. Berdasarkan hasil penelitian juga didapatkan proses co-composting pada kapasitas 100 kg memberikan laju pengomposan yang lebih rendah dibandingkan dengan kapasitas 5 kg. Selain itu perlakuan aerasi selama proses co-composting kapasitas 100 kg tidak memberikan pengaruh terhadap laju penurunan C/N. Pencapaian mutu kompos pada skala 100 Kg sudah cukup baik, dengan nilai kapasitas ikat air yang lebih tinggi dari kompos yang dihasilkan pada skala laboratorium.

Kata kunci: evaluasi kinerja, co-composting, laju penurunan C/N, kondisi proses

ABSTRACT

The research for determining the optimum process conditions of the co-composting of bagasse and filter cake had been done in a laboratory scale. However, to be applied in the industry, it is necessary to compare the performance of co-composting process of laboratory scale with those of a larger scale. The objective of this study was to compare the performance of co-composting process of bagasse and filter cake on scale of 100 kg of composting material to laboratory scale. The main performance parameters evaluated included the kinetics of the composting process and the effect of aeration rate on the declining rate of C/N. The factors maintained were in the forms of reactor geometric similarities, aeration rate, and the initial C/N. The research was carried out in aerated pile for 60 days with initial C/N of 50 and added aeration rate of 0.4 L/minute.kg for one hour per day during the first week. Observation on the scale of 100 kg showed the same process condition as the one conducted in laboratory scale reaching the temperature at mesophilic phase at 41 ^oC and 36 ^oC, pH neutral, optimum range of moisture content, and nitrate increased after the second week. Based on the results, the process of co-composting at 100 kg scale gave a lower composting rate than process at 5 kg. Moreover, aeration treatment in the first week for 100 kg scale had no effect on the rate of C/N decline. Compost quality on 100 kg scale was completed with the standard and had higher water holding capacity than compost from laboratory scale.

Keywords: performance evaluation, co-composting, declining rate of C/N, process condition

INTRODUCTION

Utilization of solid wastes of sugarcane industry such as bagasse and filter cake through co-composting process have been carried out to reduce the negative impacts of waste on the environment and provide some value added to the integrated sugarcane industry, for example as a provide`r of organic fertilizer for sugarcane plants. At the laboratory scale with the capacity of 5 kg, co-composting process of bagasse and filter cake using aerated static pile method showing the optimum condition was reached on the value of the initial C/N at 50 with active aeration of 0.4 L/min.kg which given for 1 hour at the first week of the process (Ismayana *et al.,* 2012).

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Increasing process capacity from the laboratory scale to the industrial scale was not easy, because the process conditions on both scales are different. Achievement conditions in a laboratory scale process should be first evaluated on a larger scale prior to implementation at industrial scale. Evaluated performance parameters included process conditions, change of some parameters, and mass balance. Conditions in the co-composting process including temperature, pH, and moisture content must be considered to ensure that the process would run as expected. Determination of the change rate of the compounds in the composting process will facilitate the determination of the time required to achieve the expected compost products.

Increasing of process capacity could not be separated from design of process equipment used to support the process performance evaluation at a larger scale. Wirakartakusumah *et al.* (1991) stated that the principle of geometric similarity was the foundation for capacity increased widely performed. The geometry similarity can be shown by the similarity of ratio between two lines on the first object and the ratio of represented line on the second object.

The objective of this study was to evaluate the performance of the co-composting process of bagasse and filter cake in different capacities; namely, the scale of 100 kg and 5 kg. Parameters that have been evaluated cover process conditions, nitrate, organic carbon, nitrogen, and declining of C/N.

MATERAL AND METHODS

Preliminary Research

Characterization of bagasse and filter cake was the first step in the implementation of research activities. Bagasse and filter cake were produced from the sugar industry of PT Gunung Madu Plantation, Lampung. Analysis of the characteristics was made visually by observing the shape and physical characteristics of raw materials, and conducting proximate analysis to determine the component of composting materials. Parameters analysis were the moisture content (AOAC, 1984), ash content (AOAC, 1984), nitrogen (AOAC, 1984), total carbon (AOAC, 1984), total phosphorus (APHA, 2005), potassium (APHA, 2005), and the measurement of pH (AOAC, 1984).

Determination of organic carbon and nitrogen content in bagasse and filter cake were used as a basic calculation for mixing process to the initial composition of C/N of 50. Equation formulation for determining the compost mixture composition was as follow:

$$C/N = \frac{\%\ C\ \text{baggase x weight} + \%\ C\ \text{filter cake x weight}}{\%\ N\ \text{baggase x weight} + \%\ N\ \text{filter cake x weight}}$$

Preparation of co-composting reactor was carried out by considering the size of reactor that had been done at a laboratory scale, with a diameter of 30 cm and 50 cm height. The reactor was arranged with a series of aeration systems to allow air flow to enter the compost pile. The arrangement of aeration system consists of several tools including blowers as air producer, valves were used to regulate the intake air, and flowmeter was operated to determine the amount of volume air per minute.

Primary Research

Composting was carried out by using the aerated static pile system, in which a mixture of bagasse and filter cake, whose composition was adjusted to a value of initial C/N at 50, and placed in a reactor equipped with air intake pipe. Treatment of depositing air into the material of compost was carried out actively (forced aeration) and passively. Regulation of active air intake was carried out every day in the first week with a flow rate of 0.4 L/min.kg materials. Composting process was carried out for 60 days and the observation of temperature in pile for every day and periodic observation for every week to pH, moisture content, nitrate, organic carbon and nitrogen. The series of aeration systems for co-composting process of bagasse and filter cake were indicated in Figure 1.

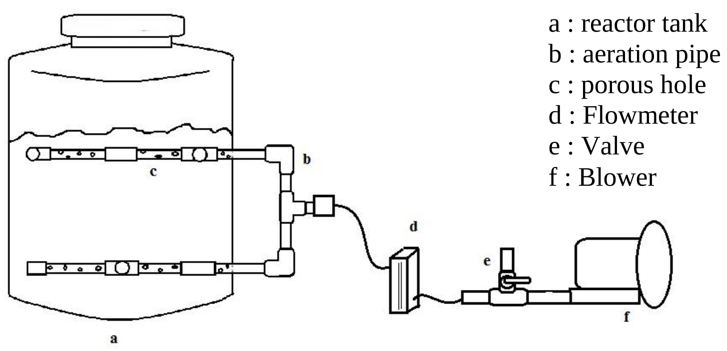


Figure 1. Aeration system for co-composting process

Parameter analysis was performed using a descriptive parameters graph with composting time, and was compared with laboratory scale (Ismayana *et al*., 2012). Meanwhile, the comparative analysis of the C/N decline rate was carried out by using a regression equation approach using software Excel. This analysis was intended to determine the composting time length to reach a value of C/N 20. The C/N decreasing rate was calculated using the following equation:

$$\text{Declining rate of C/N} = \frac{(\Delta\ C/N)}{(\Delta\ t)}$$

RESULTS AND DISCUSSION

Characterization of Materials and Mixing Formulation

Bagasse have a fairly high organic carbon 25.99 % that derived from components and cellulose fibers which remained in the stems of cane after extraction process. Li *et al*. (2013) stated that chemical structure of bagasse was dominated by cellulose and lignin. A relatively high organic carbon content but low nitrogen content made the identified C/N of bagasse was significantly high. Mixing with other materials with lower C/N allowed reduction C/N of mixed compost material, so as to facilitate the composting process.

Sugarcane juice contained adequate protein; thus when its purified, filter cake which separated has amount nitrogen content significantly. Analysis of characterization showed that nitrogen level in the filter cake was higher than those in the bagasse, but lower amount of organic C, so filter cake has lower C/N than bagasse. Some of the mineral in both bagasse and filter cake are shown in Table 1.

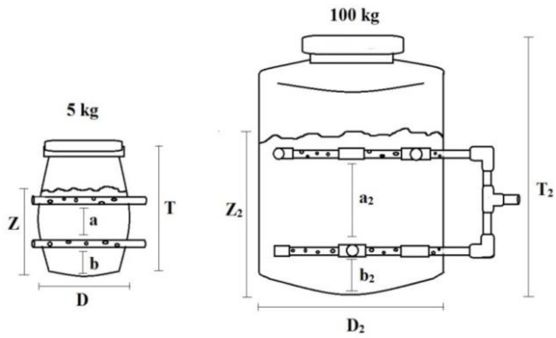
Tabel 1. Characteristic of baggase and Filter cake

Parameter	Unit	Filter cake	Baggase
C organic conten	%	9.19	25.99
Nitrogen content	%	0.24	25.99
C/N	-	38.28	0.15
Ash Content	%	16.32	173.26
Organic compound	%	18.3	4.50
Phosphor	%	0.199	31.79
Potassium	%	0.024	0.025
calsium (Ca)	%	0.258	0.024
Iron (Fe)	%	0.002	0.235
Alumunium	%	0.192	0.006
Mangan	%	0.003	0.013
Magnesium	%	0.003	0.007

Determination of the mixed compost materials compositition of bagasse and filter cake were based on the amount of C and N content. The initial C/N 50 was obtained in the composition of 86.8 kg filter cake and 13.2 kg bagasse. This composition showed that mixed compost material properties were dominated by the properties of the filter cake, and bagasse with bulky characteristics (bulking agent) could balance its the mixed material as a carbon source, lower moisture content and porosity, and help improving aeration (FFTC, 2005).

Design of Co-composting Reactor for 100 kg Scale

Factor capacity that maintained during co-composting process were similarity geometry, aeration rate, and initial C/N. Geometric principle similarity is the foundation to increase in the most widely used scale. Factor of geometric similarity of reactor which used in laboratory scale and scale of 100 kg are shown in Figure 2.



Parameter	capacity	
	5 kg	100 kg
Reactor Height (T)	50 cm	100 cm
Reactor Diameter (D)	30 cm	60 cm
Pile Height (Z)	30 cm	60 cm
Aerated pipe interval (b)	10 cm	20 cm
Aerated pipe interval (a)	15 cm	30 cm

Figure 2. Geometric similarity of co-composting reactor in 100 kg scale and 5 kg scale

Process Conditions

Temperature

Temperatures increased as a result of degradation process of organic matter were not much different between capacity of 5 kg and 100 kg. The temperature rose at the beginning of the first week and declined towards the end of composting process.

Increasing in temperature occurred only at mesophilic phase because of presence of activities in the air in aerated static pile. Air movement in pile cause the heat lost from the compost pile. Ahn *et al.* (2009) suggested that change of composting temperature was caused by condition of heat equilibrium between it was produced form microorganisms process and lost by means of convection, conduction and evaporation. The maximum temperature with 100 kg capacity was

41°C higher than those of the capacity of 5 kg which was only 36ºC. However, regarding the achievement of a stable temperature as an indicator of the maturity of the compost product, it was found that the process of co-composting with a capacity of 5 kg showed a relatively less time, on day 22th, whereas in the capacity of 100 kg that occurred after the 45th day.

Provision of active treatment aeration processing capacity of 100 kg at the beginning of the first week showed an increase in temperature compared to passive aeration although it was not very significant. The increase in temperature showed the same decrease in not only active but also passive aeration in the following weeks, until it is stable on day 45th. The change of temperature condition was shown on Figure 3.

Condition of pH

The condition of the composting process conditions would be optimum at pH around neutral or when reaching 6-7.5 (FFTC, 2005). This condition was completed in composting bagasse and filter cake on 100 kg and 5 kg scale capacity within approximately neutral conditions during the composting process. There were different conditions of pH at the beginning of composting process, in which pH values were significantly lower on 100 kg scale than that on the 5 kg scale. This condition was caused by the high proportion of filter cake with low pH around 4.1 (Meunchang *et al.,* 2005). At 100 kg scale, the initial pH compost material was 5.16 and increased in line with composting process. Figure 4 showed the changes of pH value during the co-composting process.

These had showed the formation of ammonium in addition to degradation of organic matter that producing organic acids. Ismayana *et al.* (2012) stated that an increase in initial pH value indicated that the degradation of organic material as organic acids was not the dominant process in comparison with the formation of ammonium which would increase pH.

Moisture Content

There were no difference in moisture content for both 100 kg and 5 kg scales (laboratory scale), showing relative stable in value ranged from 70-75% at scale 100 kg and ranged from 61-78% at laboratory scale. These conditions include optimum condition for moisture content on co-composting process. Isroi (2008) pointed out that moisture content below 40% could cause heat loss so that microbial activity was reduced, while when moisture content is above 80%. Volume of air was reduced and anaerobic process producing odor that occurred. Changes in moisture content at the the process were depicted in Figure 5.

Nitrate

Nitrate was generated at the end of the aerobic composting process through a nitrification process. During the process, changes of nitrate on scale 5 kg and 100 kg had found difference, especially at the beginning of processes. At scale of 100 kg, nitrate decreased up to two weeks, and increased and then stable in the following weeks. This was in contrast to 5 kg scale composting which nitrate that showed not declining at the beginning of composting, and began to increase in the second week. The condition of changes nitrate on the co-composting process were shown in Figure 6.

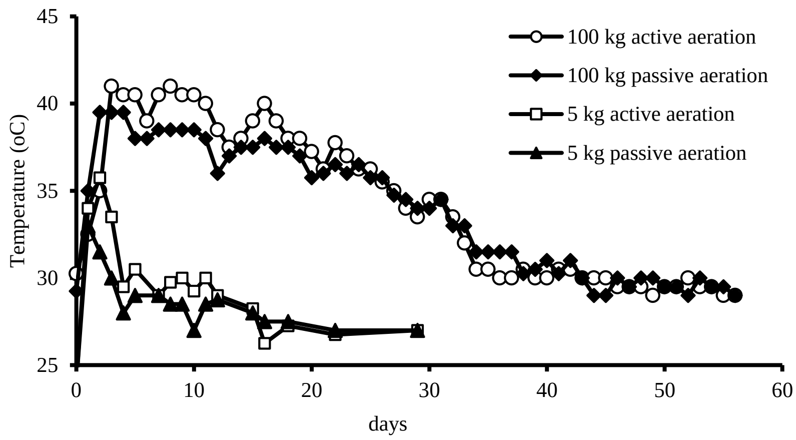


Figure 3. Temperature condition of co-composting process

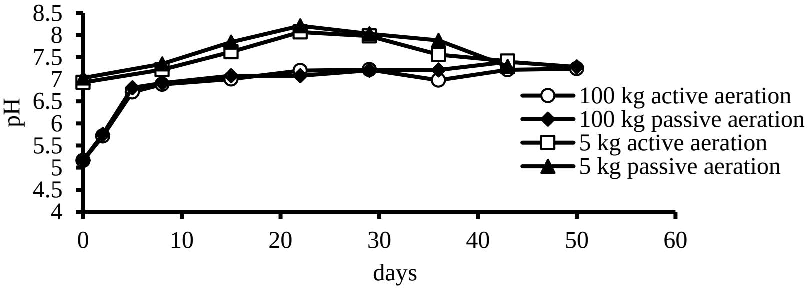


Figure 4. Changes of pH value on co-composting process

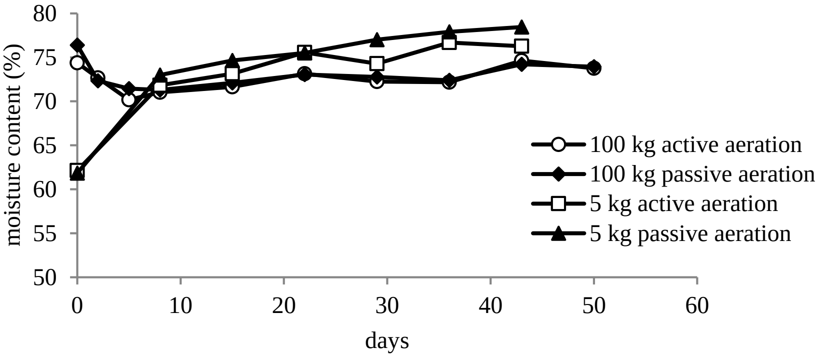


Figure 5. Changes of moisture content on co-composting process

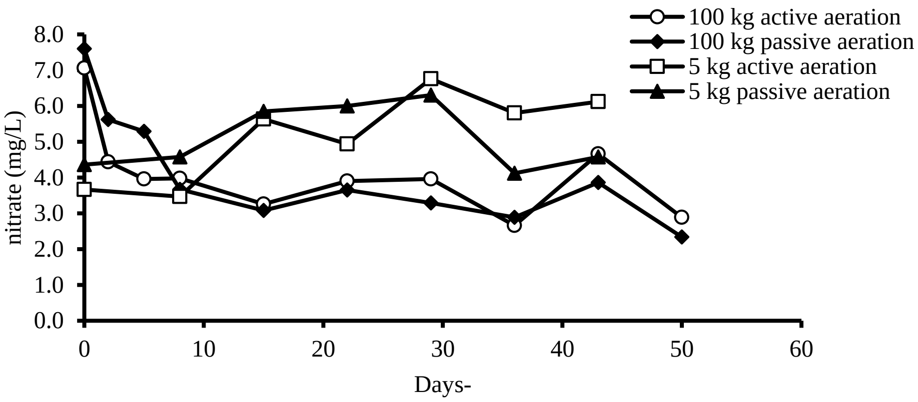


Figure 6. Changes of nitrate concentration during the process

Meunchang *et al* (2005) indicated that a relatively high temperature in initial composting stages could cause inactive formation of nitrate. Increasing of nitrate at scale of 100 kg occurred at the third week when temperature was below 30 ^{o}C. On laboratory scale, it increased in the second week when temperature was below 28^{o}C. Decreasing nitrate on scale of 100 kg could also be caused by changes to ammonium that raising of pH, besides of the degradation of organic matter. Guo *et al*. (2012) stated that inhibiting factor of nitrifying bacteria growth and activity was ammonia accumulation and higher temperature.

Changes of C/N

Changes of organic matter on aerobic composting process had been occurred due to oxydation process which produced carbondioxyde, water and biomass (Tripetchkul *et al*., 2012). The decrease of organic carbon on scale of 100 kg and 5 kg were found to be different in the first two weeks of the composting process. It showed that degradation rate on scale of 5 kg tended to be faster than 100 kg. This revealed that organic matter degradation on a scale of 5 kg required a considerable adaptation phase. The reduction trend of organic carbon on a scale of 100 kg was indicated by rising temperature that was occurring at week 4 and 5. Declining of organic carbon at the following weeks was demonstrated by decelerating trend accompanied with the decrease of microorganism activity that was caused by carbon depletion, revealed by indicating to determine of compost maturity.

There was no significant difference on nitrogen changes on scale of 100 kg and 5 kg in bagasse and filter cake composting processes. Changes in nitrogen (Figure 7) had tended to be stable from the initial process to the end that was indicating that the process did not have loss of nitrogen through evaporation due to either extremely high pH or high temperature. Strauss (2003) stated that the loss of nitrogen during the composting process could reduce the value of compost as fertilizer and affect crop yield. This supported that the advantages of using aerated static pile composting method which was resulting in not too high temperatures (thermophilic) and the pH stability in the neutral range. Furthermore, loss of nitrogen when reversal of compost pile could also be reduced with the provision of air through holes in the aeration pipes.

The changes in the value of C/N on composting process were an indicator of the maturity of compost product that be characterized by a relatively stable value at the end of composting. Relatively faster decrease of organic carbon content on scale of 5 kg caused C/N on this scale dropped faster than that on 100 kg scale. In the former, C/N tended to reach stability after day 30, while the latter still showed a decrease in day 30th. This was also shown by the increase in temperature until day 40th and 50th. Figure 8 indicated changes in the value of C / N in the process of co-composting of bagasse and filter cake.

Decline rate of C/N between process on scale of 5kg and scale of 100 kg showed significant difference in the first week, namely 0.35 per day for process of 5 Kg and 1.4-1.9 per day for 100 Kg. Its difference could be possible that carbon decreasing was greater in large-scale, or nitrogen increasing in laboratory scale. However, approaching the phase of maturity, the rate of decline of C/N on a large scale (1.05-1.19 per day) becomes smaller than the laboratory scale (1.56 per day). On a large scale, bagasse components in the mixture requires a long time for the breakdown.

The determination of composting time referring to a C/N compost standard reference value of SNI 19-7030-2004 (C/N of 20) showed the time needed for the composting process with a capacity of 5 Kg scale, taking for 22 days with decline rate of C/N covering 1.56/day. Whereas, the number of days for composting was very fast compared to the 100 kg scale composting, taking up to 29 days (active aeration) with C/N decline rate was 1.05/day.

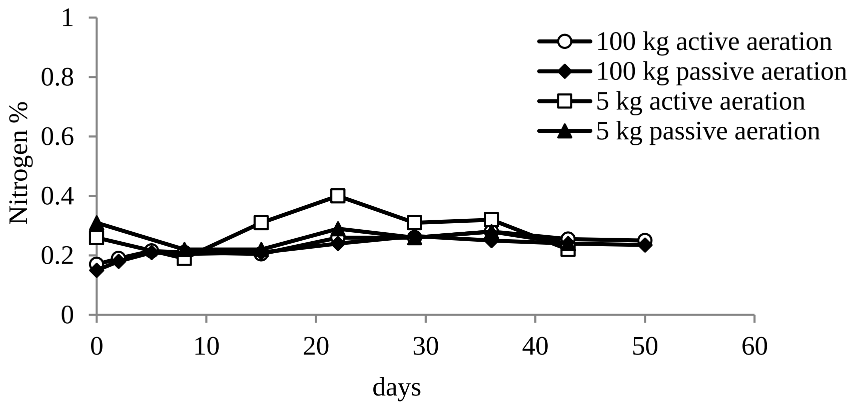


Figure 7. Changes of nitrogen on co-composting process.

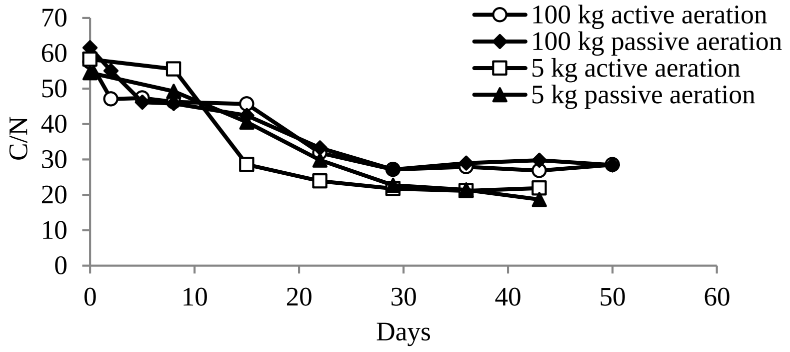


Figure 8. Changes of C/N in co-composting process

Compost Quality

Compost product of the co-composting bagasse and filter cake showed the physical properties and characteristics in accordance with the appearance of blackish-brown, earthy and smooth texture. Cahaya and Nugraha (2008) stated that mature compost smelt like earthy and blackish-brown which were formed due to effect of organic matter which was stable, and its final shape did not resemble its original form as a result of a natural decomposition by microorganisms living in compost.

The results of the analysis on the characteristics of compost showed a neutral pH from 7.22 in active aeration and 7.35 for passive aeration. The end C/N also indicated that compost was mature; namely, 17.55 for active aeration and 18.5 for passive aeration. This suggested that aeration did not seem to affect the end C/N value. Parameters for end pH and C/N were in accordance with SNI 19-7030-2004 standard; in which pH ranged was between 6.80-7.49 and C/N was between 10-20. However, other parameters such as potassium (K_2O) which was a macro element, did not meet the ISO standard. Based on the results, potassium of product was from 0.109% to 0.103% for all treatment of process, and based on SNI 19-7030-2004 potassium levels were at least 0.2%. Level of potassium in compost was influenced by the initial composting material and the main substances in the form of bagasse and filter cake used in this co-composting process had a relatively low content of potassium.

Compared to compost quality produced at a capacity of 5 kg, it was shown that there was a significant difference in the water holding capacity parameters. Analysis of compost showed that water holding capacity of compost produced results on the capacity of 5 kg was 51.28 %, while on the capacity of 100 kg the value was 99.6 % and 97.3 %. Regarding the amount of organic material effect on water holding capacity, the smaller the amount of organic matter so the smaller the amount of water or nutrients absorbed or retained. In other words, the quality of compost from both 5 kg and 100 kg capacity had met the SNI 19-7030-2004 standard.

Mass balance was an essential component to determine the final acquisition of a compost that produced and mass conversion in the process. At the beginning of composting, material inputs used include 13.2 kg of bagasse , 86.8 kg of filter cake and 43 liters of water ; thus, the total input amounted to 143 kg. During composting period, material shrinkage occurred as a result of the decomposition of organic material into simple elements accompanied by the release of gases such as CO_2 and H_2O. Depreciation was proven by height reduction pile from 60 cm to 45 cm.

After drying and sieving, the compost obtained weight was 53.7 kg and the yield from the raw material was composted by 38 %. In detail, the mass balance calculation from the beginning to the end of the process was shown in Figure 9.

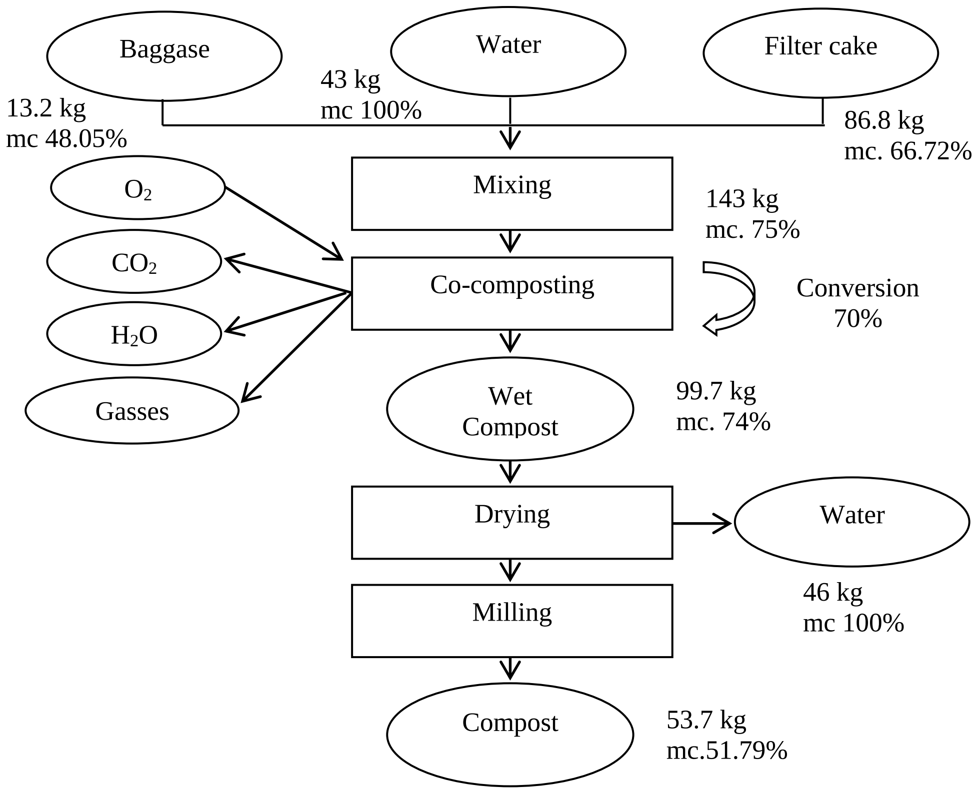


Figure 9. Mass balance of co-composting process on 100 kg scale

CONCLUSIONS AND RECOMMENDATION

Conclusions

Conditions of the co-composting process of scale of 100 kg indicated similar achievement to laboratory scale process conditions, temperatures reaching mesophilic phase, the pH in neutral condition, and moisture content condition could be maintained during the optimum process. The same conditions were also found in the formation of nitrate beginning after the second week. The significant performance difference, however, was observed in the value of C/N decline rate between scale of 5 kg and 100 kg that could achieve 1.56/day compared to 1.05-1.19/day respectively. This difference was caused by the relatively vast degradation rate of organic carbon on scale of 5 kg so that composting time was faster than 100 Kg. The resulting compost quality was fairly good, and there was an increase in water holding capacity of compost on scale of 100 kg compared to the one in laboratory scale.

Recommendation

Study on an industrial scale needs to be conducted to improve the value added of sugar industry waste such as bagasse and filter cake, including the economic feasibility analysis.

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