

Changes of Nitrogen and Organic Compound During Co-Composting of Disposable Diaper and Vegetable Wastes on Aerobic Process

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ABSTRACT

The use of disposable diapers is increasing every year, increasing generated diaper wastes every year. In Surabaya, diaper wastes have become an important issue when they are not treated properly. These diaper wastes will end up in water bodies and cause pollution. One of the technologies that can be used to treat diaper wastes is composting. Disposable diaper wastes consist of high lignocellulose and C content. It is necessary to mix diaper wastes and other wastes with high N content as a co-substrate, so that the optimum C/N ratio of composting can be achieved. In this research, vegetable wastes were used. The Objective of the research was to determine the effect of vegetable wastes adding as a co-substrate in composting of disposable diapers and volatile solid (VS), C-organic, and Total Nitrogen (TN) content changed during the composting process. The research was carried out with three variables mixtures of diaper wastes and vegetable wastes. Two control consist of 100% diaper wastes and 100% vegetable wastes. The Total weight of raw materials was 10 kg for each reactor. The composting process is carried out aerobically with a composting time of 60 days. The results showed that vegetable wastes have the potential to be used as a co-substrate for diaper wastes. The content of C-organic, VS and total nitrogen decreased. All of the parameters include C/N ratio meet the Indonesian Standard of compost.

Keywords: aerobic, C/N ratio, composting, diaper wastes, vegetables waste, volatile solid.

INTRODUCTION

The use of disposable diapers is not only for the needs of babies but also the elderly and sick people, therefore, the number of disposable diaper wastes continues to increase every year. These diapers wastes are the fourth largest composition in Surabaya. In general, these wastes are disposed of in landfills without prior processing. Most household wastes can be used as raw material for compost. Household-scale composting will reduce the volume of waste that must be transported to the landfill and the compost can be used as organic fertilizer for household purposes. Some of it is thrown into water bodies, thus polluting the river.

Diapers consist of 4 layers (Baldwin, et al., 2001), the first layer contains polypropylene and

lotion. The second layer consists of cellulose and polyester. The third layer consists of a superabsorbent polymer gel which is usually mixed with cellulose. Urine will be locked and stored in a superabsorbent polymer. The fourth layer or the outer layer of the diaper is made of polypropylene fabric whose function is to prevent liquid from leaking from the diaper. The content of cellulose polymer compounds (Colon et al., 2011) cause a high C/N ratio. This is what makes disposable diapers difficult to decompose by microorganisms, because the optimum C/N ratio for composting is 20–40 (Tchobanoglous et al., 1993; Chen et al., 2011). Disposable diapers have the potential to be used as raw material for compost, if other organic materials with high N content are added. One of the wastes that can be used as co-substrate

is vegetable waste because it contains a low C/N ratio (Kumar et al., 2010; Musa et al., 2020), so it is suitable if mixed with waste containing a high C/N ratio. Apart from households, large amounts of vegetable wastes can be obtained from agricultural activities, supermarkets, and markets (Pavi et al., 2017). Vegetable waste has a high level of moisture and biodegradability (Yuanyuan et al., 2016) and increase the N content in compost products (Kim et al., 2018). The combination of disposable diapers and vegetable waste is suitable for use in household composting. This combination still requires the addition of chemical fertilizers so that the optimum C/N ratio can be met.

The composting process can be done both anaerobically and aerobically. Because the application of this research will be applied on a household scale, the aerobic process was chosen. The aerobic process takes place more quickly (Ponsa et al., 2008) and does not cause odor. The results of the compost are also drier, so they do not require the process of maturation and drying. This study aims to compare the effectiveness of adding vegetable wastes as a co-substrate in composting disposable diapers with an aerobic process and changes in Volatile Solid, C-organic and Nitrogen content during the composting process.

MATERIALS AND METHOD

Materials

The diaper wastes used in this study was solid wastes taken from the baby care home. Diaper wastes are cleaned from baby feces and then dried naturally. Vegetable wastes are obtained from traditional market around the ITS campus, Surabaya and urea is purchased from commercial shops.

Experimental design

Diaper wastes and vegetable wastes were chopped manually to be size of less than 5 cm. The smaller the particle size, the faster waste decomposition takes place (Bolado-Rodriguez, et al., 2016). If the particle size is too large, the surface area will be smaller so that the microbes are less able to decompose the material (Verma and Marschner, 2013). According to Duong et al. (2012) small particle size can produce high levels of N and P. Then the diaper wastes are mixed with vegetable wastes with the addition of urea

as much as 10 gr per each reactor. Total mixed weight of each reactor was 10 kg. The compost material was put into a perforated reactor with a volume capacity of 50 liters. The reactor is covered with gauze, so that air can enter freely. Stirring is done every 3 days, so that no part of the waste is deprived of oxygen. The research variables were carried out by mixing the diaper wastes and vegetable wastes, which the ratio of diaper wastes and vegetable wastes as follows: $R_1 = 10:1$ (diaper wastes only); $R_2 = 7:3$; $R_3 = 5:5$; $R_4 = 3:7$ and $R_5 = 0:10$ (vegetable wastes only). The research was conducted for 60 days. The parameters analysis can be seen in Table 1. The quality of the compost produced was compared with the Indonesian Standard for Compost (SNI).

RESULTS AND DISCUSSIONS

Temperature and moisture content relationship

Figure 1 shows the temperature changes that occurred during composting processes. At the beginning of the composting the temperature of each reactor was 29.2°C. The temperature increased sharply until day 3th and then decreased sharply until day 6th. After that the temperature fluctuated, but decreased slowly until it reached a temperature of around 30°C on day 30th. Then the temperature stabilized until the end of composting, reaching a temperature of about 29°C on day 60th.

The metabolism of organic matter by microorganisms released heat which caused the temperature inside the reactor increased. The temperature in this research was not more than 47.2°C, so it can be concluded that only mesophilic microorganisms were able to reproduce and metabolize the available organic matter. Types of microorganisms that can be more effective in decomposing waste in a mesophilic manner are proteobacteria and fungi (Tang et al., 2007). The initial water content in reactor R_1 , R_2 , R_3 , R_4 and R_5 were

Table 1. Parameters analysis method

Parameter	Analysis method
C-Organic	Black and Welkey
N total	Spectrofotometer
Water content, total solid and volatile solid	Gravimetry
pH	pH indicator
Temperature	Thermometer

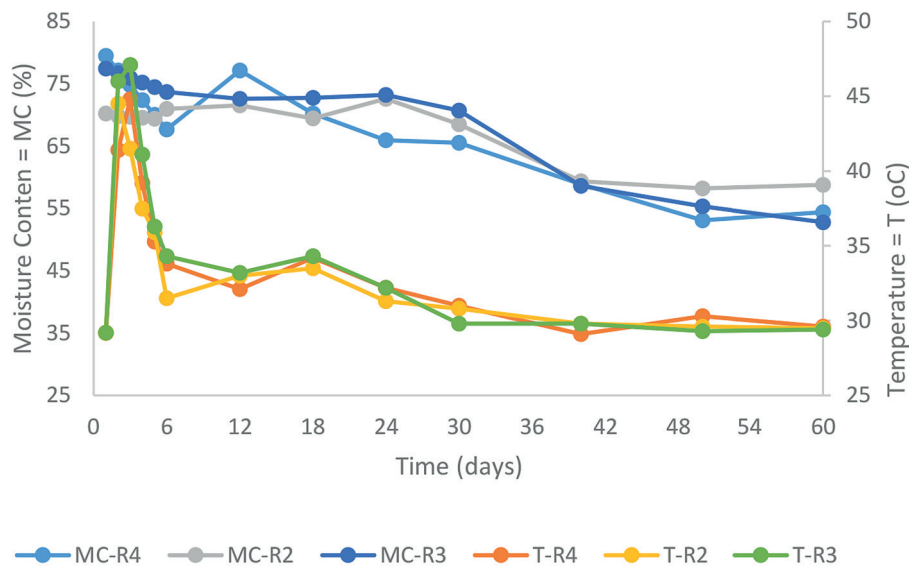


Figure 1. The relationship of temperature and water content decrease

78.83%; 70.26%; 77.45%; 79.49% and 66.67% respectively, where based on Ahn et al., (2008) research the optimum composting water content ranges from 60–80%. For composting organic waste, relatively high moisture contents are better at achieving higher temperatures and retaining them for longer times (Makan et al., 2013). If the temperature increased, water content will drop, it will cause the water shortage, so inhibit the microbial metabolism (Rastogi et al., 2020). After the sixth day, the water content varies from 50 to 60%. Based on Li et al., (2021) research, moisture content around 53% is effectively prevented leaching and nutrient loss, which is in accordance with the results in this study (Figure 3). At the end of composting, the water content of R_1 , R_2 , R_3 , R_4 and R_5 was 57.21%; 58.78%; 52.8%; 54.41%; and 53.65%. This water content is slightly higher than the compost standard (SNI) where the water content is 50%. After the composting process, the compost is continued with the next stage, namely the cooling and maturation process where drying also occurs which reduces the water content, so that the maximum moisture content of the compost can be achieved.

pH at reactor R_1 , R_2 , R_3 , R_4 and R_5 was 7.56; 8.18; 7.91; 7.95 and 7.1. The pH value during the composting process fluctuates. Changes in pH indicate the activity of microorganisms in degrading organic matter. Metabolic activity of various heterogeneous group of microorganisms results in increased temperature as these microbes utilize the N and C of the organic matter for their body

assimilation. Bacteria utilize soluble compounds such as sugars, amino acids and lipids found in the raw material of compost, which produces organic acids and hence, the pH can drop (Sanchez et al., 2017; Meena et al., 2020). The optimum pH for the composting process ranges from 6.5–7 (Zhang et al., 2016). If the pH is too low, it will inhibit the growth of microorganisms, slow the temperature rise and prolong the composting time (Jiang et al., 2014).

Changes in total solid and volatile solid content during composting

The increase of Total Solid in all reactors at the end of composting was around of 20.51% to 33.33%, as can be seen in Table 2. During the composting process, the total solid content increased because some of the volatile solids had been metabolized by microorganisms. This increase in total solid pocket indicates the activity of microorganisms. The decreased of VS in each reactor can be seen in Table 3. The initial contents of each R_1 , R_2 , R_3 , R_4 and R_5 were 82.9; 79.17; 77.32; 68.87 and 82.07. The decrease in VS content varied by 5% in diaper waste (R_1) to 64% in vegetable waste (R_5). The addition of vegetable wastes can increase the rate of decrease in VS levels (R_2 , R_3 and R_4) when compared to without the addition of vegetable waste (R_1). The decrease of VS in the R_3 mixed reactor was achieved by 12.73% for 60 days. Based on Cabanas-Vargas et al. (2005) research, VS was degraded by 28%

Table 2. Total solid content

Days	0	6	12	18	24	30	40	50	60	Increased
(%)										
R ₁	21.17	25.49	26.36	27.24	24.46	33.04	41.41	42.23	42.79	102.13
R ₂	29.74	29.04	28.46	30.56	27.39	31.46	40.63	41.77	41.22	38.60
R ₃	22.55	26.29	27.40	27.24	26.78	29.30	41.38	44.66	47.20	109.31
R ₄	20.51	32.33	22.84	29.76	34.07	34.48	41.11	46.90	45.59	122.28
R ₅	33.33	55.47	47.59	49.54	52.34	56.18	48.51	45.16	46.35	39.06

Table 3. Volatile solid content

Days	0	6	12	18	24	30	40	50	60	Decreased
(%)										
R ₁	82.90	81.51	74.56	82.65	75.36	77.20	75.95	77.17	78.55	5.25
R ₂	79.17	76.93	72.91	81.33	69.66	71.56	78.40	71.06	74.28	6.18
R ₃	77.32	77.28	75.55	80.63	66.72	63.44	67.48	73.53	67.48	12.73
R ₄	68.87	73.24	79.41	68.25	56.07	55.37	60.34	59.20	60.34	12.39
R ₅	82.07	62.34	53.31	53.08	55.93	49.94	40.22	49.53	29.04	64.62

during the 8 weeks of the composting process, while in the study of Lemus and Lau (2002) VS degradation reaches 20% during 10 days. Diaper degradation is slow because all diaper materials are used as raw materials contains plastic. To get better results, plastic should be separated from other materials and not composted. The decrease in VS content until day 24th indicated that microorganisms degrade organic matter that is easily decomposed (Bernal et al., 2009). The composting process is maintained under aerobic conditions, by turning the pile of garbage every three days and the reactor is perforated for air in and out. The composting process will produce CO₂, CO, CH₄, H₂, H₂O, NH₃ and H₂S which is released into the ambient air (Esparza et al., 2020).

Changes in C-organic content during composting

The decrease in C-organic content occurred in all reactors as can be seen in Figure 2. At the beginning of composting, the C-organic content of R₅ was the lowest, according to the compost raw material which only contained market wastes. After mixing, the initial C-organic content in each reactor ranged from 50–60%. The decrease in organic C content in R₁, R₂, R₃, and R₅ from the first to the sixth day occurred rapidly, where the decrease in R₄ was the fastest. While at R₂ measurement of C-organic content there was an increase.

The increase in C-organic content can be measured, if at the time of sampling the test material taken contains plastic. In this study, diaper wastes are not separated from plastic raw materials. It facilitates the preparation of compost raw materials, if composting will be applied on a household scale. After linearization of the graph of the decrease in C-organic content, the correlation number of R₂ at R₁, R₂, R₃ and R₄ ranged from 0.68 to 0.78 except for R₅ the R₂ value was 0.39. From the R₂ value, it can be concluded that the composting process follows the reaction rate of first order. R₅ should also follow the reaction rate of the first order, but because the raw material are vegetable wastes which contains high lignocellulosic content, a longer composting time is required. Or to shorten the composting time, pretreatment is needed to break down the lignocellulose, before composting is carried out. The results of linearization obtained that the reaction rates of R₁, R₂, R₃, R₄ and R₅ were -0.70; -0.68; -0.60; -0.72 and -0.22 respectively.

If the values of R₁ and R₄ are compared, where the initial C content is almost the same, then the addition of vegetable wastes only increases the rate of composting by 0.02. Although the N content in diaper wastes is very limited, microorganisms from feces and urine can still metabolize diaper wastes. The nitrogen content in diaper wastes comes from the baby's urine. Urine is perhaps the most promising product as it contains relatively

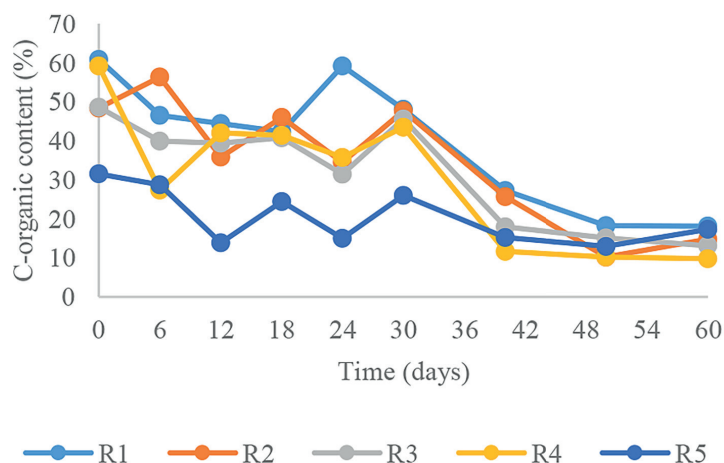


Figure 2. Decrease of C-organic content

high concentrations of N (up to 9 g N/l), P (around 0.7 g P/l) and other nutrients such as K, sulphur (S), and micronutrient (Winker et al., 2009). The Food/Microorganism (F/M) ratio is very important in the success of the biological waste treatment process (Guo et al., 2017). The results of this study indicate that the addition of vegetable wastes can increase the rate of composting diaper wastes at the ratio of the composition of diaper wastes and vegetable wastes by 3:7.

Total nitrogen content during composting processes

Total Nitrogen (TN) is the sum of nitrate-nitrogen ($\text{NO}_3\text{-N}$), nitrite-nitrogen ($\text{NO}_2\text{-N}$), ammonia-nitrogen ($\text{NH}_3\text{-N}$) and organically bonded nitrogen. Nitrogen is the main element in the composting process because nitrogen contributes to the growth of microorganisms (Campitelli and Ceppi, 2008). During the composting process, a nitrogen cycle occurs which includes ammonification, nitrification, assimilation, immobilization and denitrification. Initial TN content of R_1 , R_2 , R_3 , R_4 and R_5 was 0.3; 0.31; 0.42; 0.38, and 0.5 respectively. The total nitrogen content in reactors R_2 , R_3 and R_4 increased until the day 30th by 75.83%, 73.15% and 70.22%, whereas control reactors R_1 and R_5 increased by 64.96% and 83.80% as can be seen in Figure 3. Control reactors R_1 and R_5 , total nitrogen content decreased by 45.73% and 62.68%, while the reactors R_2 , R_3 and R_4 were 69.62%, 56.74% and 21.01%. The greatest decline occurred on reactor R_2 . At the end of composting, it can be seen that the compost in all reactors met the minimum standard for TN

content, which was 0.4%. Increasing the TN content in each reactor concluded that the addition of vegetable waste can increase the N content in the diaper waste composting process.

C/N ratio

The C/N ratio is one of the factors that affect the composting process and quality (Zhu, 2007; Zhang and Sun, 2016). In this study, the value of the C/N ratio was obtained from the comparison of the value of C-Organic with Total Nitrogen. In this study, the initial C/N ratio was very high, even though urea was added as the source of N. At the beginning of composting the C/N ratio was greater than 40 as can be seen in Fig.4. But, composting process continued even though it is slow, because of the sufficient number of microorganisms. According to El Haggag (2005) decomposition of the organic waste material will slow down if C/N ratios are as low as 10:1 or as high as 50:1. The high C content causes the microorganisms to lack N which inhibits the proliferation of microorganisms. If C/N ratio decreased below 15, the compost had satisfied an acceptable standard of maturation (Bernal et al., 2009), while according to SNI below 20. The C/N ratio of R_4 was reached 11 in the 40 days and R_5 was reached 10.3 in the 6 days.

CONCLUSIONS

Vegetable wastes has the potential as a co-substrate to increase the composting rate of diaper wastes. The composting process occurred

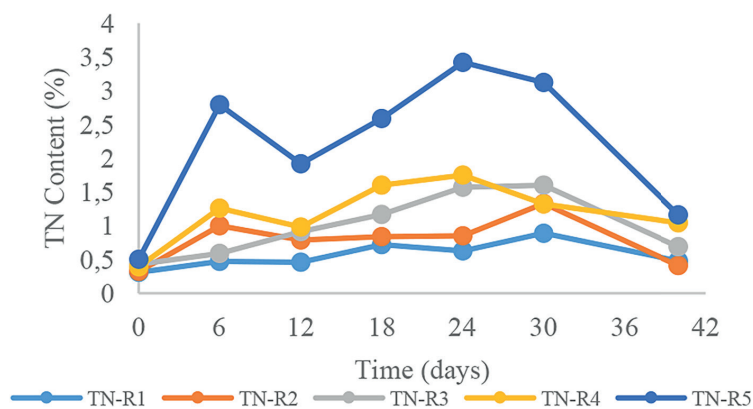


Figure 3. TN content during composting processes

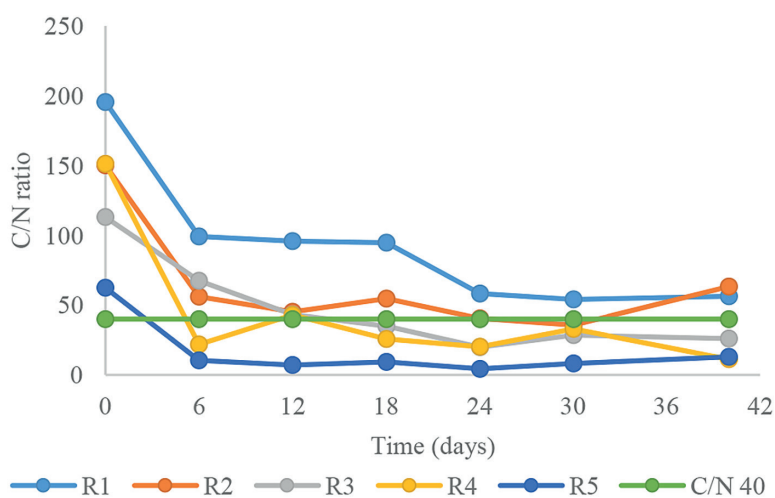


Figure 4. C/N Ratio during composting processes

throughout all reactors by utilizing microorganisms found in diaper wastes and vegetable wastes. The quality of the compost in the R₄ met the Indonesian national standard compost for pH, temperature, C, N, VS and moisture content.

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