THE EFFECT OF WATER CONTENT AND C/N RATIO OF A MIXTURE OF COW DUNG AND *Albizzia falcata* SAWDUST ON THE CHANGE OF pH AND TEMPERATURE OF COMPOSTING PROCESS AND THE NUTRIENT CONTENT OF RESULTED LIQUID ORGANIC FERTILIZER

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Abstract

This study was performed at the Faculty of Animal Husbandry, Universitas Padjadjaran Indonesia. It was aimed to identify (a) the effect of water content and C/N ratio of a mixture of cow dung and Albizzia falcata sawdust on the change of pH and temperature of composting process, (b) water content that provides the highest change in pH and temperature of composting process, (c) to what extent the C/N ratio of the mixture influence the concentration of nitrogen, phosphorus and potassium in the resulted liquid organic fertilizer. This study was divided into two experiments. The first experiment was done in order to answer the first two aims, a solid state composting process. It was based on completely randomized design (CRD) with three water content treatments, namely WT_1 = 40%, WT_2 = 50% *and* WT_3 = 60%. *Each treatment was replicated for 6 times. The second experiment was carried out for answering the last aim of the study, converting the solid compost into liquid fertilizer. This experiment was also based on CRD with three C/N ratio treatments, i.e.* CN_1 = 20, CN_2 = 25 *and* CN_3 = 30. *The treatments were performed in six replications. Tukey test was then performed to determine the difference among treatments of the consecutive experiments. The result of the study shows that water contents of the mixture are not significantly influencing the change of pH and temperature of composting process. However, the highest change of the pH and temperature were obtained from water content of 40%. Furthermore, the result of the study shows that* CN_3 *provides significant effect on nitrogen and phosphorus contents of liquid organic fertilizer in comparison to* CN_1, *but not to* CN_2. *Finally, only* CN_3 *provides significant effect on potassium content of the fertilizer.*

Key words: C/N ratio, composting, cow dung, liquid organic fertilizer, sawdust

INTRODUCTION

Intensive dairy cow farming leads to solids disposal problems worldwide. In Indonesia, cow dung is commonly applied to farmland as manure directly from the stall; therefore, it frequently causes environmental problems particularly air pollution and water pollution. It will be more valuable if it is converted into an organic fertilizer by mean of composting prior to its application on farm land. There are two types of organic fertilizer, namely solid fertilizer and liquid fertilizer. Recently, liquid fertilizer is more popular in the society rather than solid one due to its effectiveness in improving soil fertility. Liquid fertilizer is made in two steps. Firstly, compost feedstock is fermented using indigenous microorganisms in solid state, and then fermented in liquid state.

The quality of organic fertilizer is highly depending on the composting materials or feedstock, physically, chemically and biologically. Although cattle dung has been used for this purpose since ever, it has some limitation for solid composting process, particularly its water content and C/N ratio. Water or moisture is necessary to support the metabolic activity of the microorganisms. Feedstock should maintain moisture content of 40-65% (Misra, et al., 2003). Cow dung has high water content, about 80% (Merkel, 1981). This water content will influence the first step of fermentation. In making organic fertilizer, water content is one of important factors that should be provided. Microorganisms involve in fermentation process require water for their life and activities. Nutrient in the organic substance can be absorbed by microorganisms only if diluted in water (Stoffela and Khan 2001). Water content of feedstock during solid fermentation should be maintained in the range of 40 to 60%. If the feedstock too dry, composting occurs more slowly. While a water content in excess of 65 % the interstitial space of the feedstock particles will be filled with water and the feedstock become anaerobic (Handrek, 1979). Consequently, there will be no oxygen available for aerobic microorganisms, and fermentation will continue in anaerobic condition. This condition may loss some nutrients and unexpected products will be resulted, such ammonia and sulfuric acid. Moreover, when the feedstock is too wet, fermentation will continue in low temperature causing some pathogen remain a life, particularly thermophilic bacteria. Therefore, the water content of the feedstock adjusted very well. In practice, it is advisable to start the feedstock with a moisture content of 50-60 %, finishing at about 30 % (Misra, et al., 2003). There are many ways of decreasing water content of cow dung, i.e., air drying, sun drying, heat drying, and dry material adding. The first three drying is good enough when the volume of feedstock is low, but if the volume of the feedstock is high the drying process will troubling. Adding dry material into feedstock not only decrease water content, but also increase some nutrient content that may useful for supporting fermentation process.

As a waste, cattle dung is still containing high amount of nutrients, i.e. nitrogen 1.4 – 2.8 %, phosphorus 0.5-1.01% and potassium 0.5-0.6%.(Misra, et al., 2003), depends on the animal origin. This is very beneficial, because microorganisms involve in the fermentation process require carbon, nitrogen, phosphorus and potassium as the primary nutrients. Of particular importance is the C/N ratio of feedstock. The optimal C/N ratio of feedstock is between 25 and 30 (Bass, 1992), although ratios between 20 and 30 (Handerk, 1979) or even wider between 20 and 40 are also acceptable (Misra, et al., 2003). However, it has been experienced, cow dung has very low C/N ratio of about 19 (Gaur, 1983) or even lower that is 15 (Leonard, 2001). This ratio may influence the activity and the growth of microorganism involve in both steps of fermentation. If the ratio is too high (above 40) the growth of microorganisms is limited, the fermentation process will be very slow and resulting in a longer composting time. In this case, microorganisms involve in the process get more carbon as the source, but less nitrogen. In contrary, if the ratio is too low (less than 20) it may leads to underutilize of nitrogen and the excess may be lost to the atmosphere as ammonia or nitrous oxide. These two products has annoying odor that can be a problem. This ratio may influence the activity and the growth of microorganism involve in both steps of fermentation. To improve the C/N ratio, it is necessary to mix cow dung with other organic substance which has high C/N ratio, e.g. straw with C/N ratio of 100 or wood shavings with C/N ratio of 600 (Leonard, 2001).

Beside those two factors, fermentation process also requires others factors, such as pH and temperature. The pH should be about 6.5 to 8.5 (Stofella and Khan, 2001). In the beginning of composting process, pH of substrate declines due to acid formation, and then inclines again along with microbial magnification reaction, which converts organic nitrogen into ammonia (Merkel 1981). Although the natural buffering effect of the composting process lends itself to accepting material with a wide range of pH, the pH level should not exceed eight. At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere. Fermentation is divided into two stages, called mesophilic stage and thermophilic stage. In the mesophilic stage, microorganisms are active at temperature of about 32 – 43^{0}C, and break down the readily degradable component of the feedstock. This activity will rise the temperature of feedstock. In the themophilic stage, thermophilic microorganism takes place and degrades the organic material. Temperature at the center of feedstock rises to 49 - 65^{0}C (Chen and Inbar, 1993). Many important processes take place during the thermophilic stage. As the organic matter degrades, its particle size is reduced. Pathogens are destroyed as the heat in the pile climbs above a critical temperature of 55°C. Fly larvae and most weed seeds are destroyed at temperatures above 63°F (Baldwin and Greengield, 2001). Moreover, Baldwin and Greenfield (2006) stated that it is possible for temperatures in the feedstock to become too hot. When temperatures reach the 65°C to 71°C range, thermophilic organisms begin to die and composting slows. Spontaneous combustion can occur in the feedstock that becomes too hot and dry. When feedstock become to hot and dry, it is necessary to turn the feedstock to reintroduce oxygen into the feedstock. Turning may lower temperature again to about to 49 ^{0}C.

Organic substances that are available around the year in Indonesia among others are sawdust. Usually sawdust has high C/N ratio of 450 (Handerk, 1979), or in the range between 200 and 700 (Baldwin and Greenfield, 2006). One of wood species that is grown by the population is *Albizzia falcate*. This species of wood is known as fast growing wood, in 4 years it produces 40 – 50 cm wood in diameter (Indowood, 2006). Although classified as soft wood, it can be used for many purposes; therefore, it is used abundantly. It contains 40-44% cellulose, 20 – 32% hemicelluloses, and 25-35% lignin (Haygreen and Bowyer, 1996). This makes the sawdust has high C/N ratio. Since sawdust has also low water content, adding sawdust into cow dung should increase the C/N ratio and decrease water content of feedstock. In turn, this will result in a good solid fermentation process that provides a good feedstock for liquid fermentation process. Since, there is no information concerning this matter, it is necessary to conduct a study on the effect of water content and C/N ratio of a mixture of cow dung and *Albizzia falcata* sawdust on the change of pH and temperature of composting process and the nutrient content of resulted liquid organic fertilizer.

MATERIAL AND METHOD

The experiments were undertaken at the Microbiology and Waste Management. Faculty of Animal Husbandry. Universitas Padjadjaran Indonesia.

Preparation and formulation of feedstock. Before formulating feedstock, chemical analysis was done on cow dung and. The chemical analysis was done in duplex. The result of the analysis is presented in Table 1.

Table 1. Carbon and nitrogen content of cow dung and *Albizzia falcata* sawdust

Organic substance	Carbon content (%)	Nitrogen content (%)	Water content (%)	C/N
Cow dung	9.30	0.63	79.40	14.8
Albizzia falcata sawdust	53.38	0.25	13.93	213.52

Since water content was use as treatment, this feedstock is formulated using the following equation (Handerk, 1979) which is not including water content in the calculation.

$$\text{C/N ratio} = \frac{(F \times Cc) + (S \times Cs)}{(F \times Nc) + (S \times Ns)}$$

Where, F = Cow dung (kg), S = sawdust (kg), Nc = nitrogen content of cow dung (%). Ns = nitrogen content of sawdust (%), Cc= carbon content of cow dung (%), Cs = carbon content of sawdust

By substituting the results of chemical analysis on Table 1 into the equation, for C/N ratio of 30, the feedstock is then composed with 83% cow dung and 17 % sawdust. In order to obtain a volume equal to 1000 liter of water, the feedstock should be 300 kg composed with 249 kg cow dung and 51 kg of sawdust. The feedstock contains 40% water. To get feedstock with 50% and 60% water content, same water was added, i.e. 60 kg and 150 kg. This study was divided into two stages. The first stage was solid fermentation process for 20 days. This process was an aerobic process. Composting method used in this study was Berkeley method that had been developed at California University, USA (Handerk, 1979). The feedstock was piled up of 1 m^3 and turned every 3 days to maintain oxygen content. This experiment was done based on Completely Randomized Design (CRD) with three treatment of water content, i.e., W1 = 40%, W2 = 50% and W3 = 60% and six replications. The pH of the feedstock was measured every day, by taking sample every 12 am from day 1 to day 20. While, temperature is measured every three hours a day that are at 08.00am, 12.00am and 16.00pm.

The second experiment was liquid fermentation process, which is also based on CRD with three treatments of C/N ratio, namely of CN_1 = 20, CN_2 = 25 and CN_3 = 30. The treatments were performed in six replications within 21 days. After being fermented aerobically, the feedstock was submerged in warm water of 40^0C for 36 hours. After being sieved so the coarse particle separated, the liquid part was placed in bottle according to the treatment. The bottles were stopped for one week. After that, the stoppers were opened, and let the liquid feedstock being fermented again for 3 weeks. The liquid in the bottle was aerated individually. The nitrogen, phosphorus and potassium content of the resulted organic liquid fertilizer were analyzed in the Laboratory to know the effect of every treatment, the obtained data were analyzed using one way Analysis of Variance (ANOVA), this analysis was then followed by Tukey T-Test to know the inter treatments effect differences (Gaspersz, 1991).

RESULTS AND DISCUSSIONS

The result of experiment about the effect of water contents on the pH of feedstock measured at the 3rd days, 6th days, 8th days and 12th days of composting process is presented on Table 2.

Table 2. The effect of treatments on pH of the compost

No.	Composting Day	pH of Compost		
		W1	W2	W3
1	3	8.76	8.73	8.39
2	6	8.31	8.57	8.49
3	9	7.99	7.90	7.78
4	12	8.25	8.33	8.27

Note : W1 = 40% water content, W2 = 50% water content, and W3 = 60% water content

Based on Table 2, the highest pH of feedstock are 8.76 and 8,73 resulted from W1 and W2 at the 3rd days of composting process, while treatment of W3 provide the highest pH at the 6th days of composting process, that is 8.49. Moreover, Table 1 also shows that at the 9th days of composting process all treatments provide the lowest pH. All pH are then inclining again to the basic state at the 12th of composting process. However, according to the ANOVA, these treatment are not significantly influence the pH of feedstock during the composting process ($P>0.05$). It might be related to turning activity. Turning may ad some amount of oxygen that accelerates the activity of microorganisms to convert the acidic substance into basic. Besides, according to several experiments it has been known that the optimum pH of composting process is in between 6.5 to 8.5 no matter how complex the microorganisms involve in the process (Epstein, 1997 in Stoffella and Khan, 2001). The result also proves that water content of 40 to 60% resulted in optimum pH provided all influencing factor of composting are fulfilled.

During composting process, the temperature of feedstock are varies as shown on Table 3. The highest temperature of feedstock, that are 60.20^0C and 50.24^0C resulted from treatment W1 and W2 at the 3rd days of composting process. The highest temperature resulted from W3 is reached at the 12th days.

Table 3. The effect of treatments on temperature of the compost

No.	Composting Day	Temperature of Compost (^0C)		
		W1 (40%)	W2 (50%)	W3 (60%)
1	3	60.20	50.24	41.07
2	6	41.10	39.49	38.54
3	9	49.60	45.61	44.01
4	12	42.90	46.58	47.61

This finding along with Rusdi and Kurnani (1994) stated that when temperature of feedstock reaches 40^0C, mesophilic organisms will move to the outer layer of feedstock bulk, while thermophilic microorganisms continue their activities. This termophilic condition is reached after 2 – 3 days (Olds, 1968). Based on ANOVA, the water content treatments are not significantly influence the temperature of feedstock during the composting process. This might also due to feedstock turning. Again, it is proved that water content of 40 to 60% will provide similar composting process.

The result of chemical analysis of nitrogen content of the resulted liquid fertilizer is presented on Table 3. It is found that the CN_3 (C/N ratio of 30) provides the highest nitrogen content (3.085%), followed by CN_2 (CN ratio of 25) provides nitrogen content of 3.032 %, and finally CN_1 (C/N ratio of 25) provides nitrogen content of 2.920 %.

Table 4. The result of Turkey's T-Test on the effect of C/N ratio on nitrogen content of liquid fertilizer

Treatment	Nitrogen content (%)	Significance (α 0.05)
CN_3	3.085	a
CN_2	3.032	ab
CN_1	2.920	b

Note : CN_1 = C/N ratio 20, CN_2 = C/N ratio 25 and CN_3 = C/N ratio 30

The result of ANOVA shows that the treatments are significantly influence nitrogen content of the fertilizer. Therefore, Turkey's T-Test was performed. The result of the test shows that CN_3 provides no significant effect than that of CN_2, but significant of CN_1. Next, CN_2 has no significant effect than that of CN_1. Based on this result it is known that C/N ratio of 30 (CN_3) provide sufficient supply of carbon and nitrogen to microorganisms in fermenting the feedstock so that most of nitrogen retained in the fertilizer. Or in other words, there is only small amount of nitrogen loss from the feedstock. This finding is agreed with Haug (1980) stated that an initial C/N ratio of 30 or less would seem most favorable for rapid composting. Therefore, in his case C/N ratio of 30 is also an optimal C/N ratio in making liquid fertilizer from a mixture of cow dung and *Albizzia falcata* sawdust.

The result of phosphorus content analysis, as shown on Table 5, shows that CN_3 provides the highest phosphorus content (0.018%), followed by CN_2 and CN_1. After being analyzed using ANOVA, it is known that the treatment C/N ratio of feedstock significantly influence phosphorus content of fertilizer. The analysis continued with Turkey's-Test. As in the case of nitrogen content, CN_3 has no significant different effect with CN_2 , but with CN_1. CN_2 has no significant different effect with CN_1. Variation of phosphorus contents may correlates with C/N ratio. As mentioned previously, C/N content of 30 may result in the highest nitrogen content of the fertilizer. It means in this condition microorganisms grows well and utilized nitrogen and phosphorus proportionally.

Table 5. The result of Turkey's T-Test on the effect of C/N ratio on phosphorus content of liquid fertilizer

Treatment	Phosphorus content (%)	Significance (α 0.05)
CN_3	0.018	a
CN_2	0.015	ab
CN_1	0.012	b

Note : CN_1 = C/N ratio 20, CN_2 = C/N ratio 25 and CN_3 = C/N ratio 30

Microorganism obtains phosphorus by mean of mineralization using enzyme phosphatase released by the microorganism. (Yuliprianto, 1993; Stofella and Kahn, 2001). Phosphorus is used for developing protoplasm and nucleus. There are also some bacteria and fungi produce phytase which provide available phosphorus for plant. Phosphorus usually present in the form nucleic acid, phytine, and lecithin (Sutedjo, et al., 1996). Along with the availability of carbon and nitrogen, bacteria and fungi transform lecithin and nucleic acid into phosphate. Sutedjo, et al. (1996) also stated that about 66% lecithin is transformed into soluble phosphate on the 60^{th} day of fermentation. Although the period of this study is less then 60 days, the will be in line. The rest of phosphorus is assimilated by bacteria to develop cells. Based on Table 4, CN_3 provide the highest phosphorus content of liquid fertilizer. It is due to the concentration of carbon and nitrogen in the feedstock is adequate for microorganism to grow and develop, and therefore there is more feedstock material decomposed and releases some available phosphorus.

The result of chemical analysis of potassium content of the resulted liquid fertilizer is presented on Table 6. It is found that the CN_3 (C/N ratio of 30) provides the highest potassium content (0.020 %), followed by CN_2 (CN ratio of 25) provides potassium content of 0.015 %, and finally CN_1 (C/N ratio of 25) provides nitrogen content of 0.013 %.

Table 6. The result of Turkey's T-Test on the effect of C/N ratio on potassium content of liquid fertilizer

Treatment	Potassium content (%)	Significance (α 0.05)
CN_3	0.020	a
CN_2	0.015	ab
CN_1	0.013	b

Note : CN_1 = C/N ratio 20, CN_2 = C/N ratio 25 and CN_3 = C/N ratio 30

Based on Table 6, it is known that CN_3 provide the highest potassium content (0.020%) of the resulted fertilizer, followed by CN_2 (0.015%) and CN_1 (0.013%). According to ANOVA, the treatments provide significant effect on the potassium content. The effect of CN_3 is not significantly different than that of CN_2, but significant compared to the effect of CN_1. The effect of CN_2 is not significant to that provided by CN_1. Again, in this case the availability of carbon and nitrogen in CN_3 treatment is more than in CN_1. Potassium is used by microorganism as a catalyst in their metabolism: therefore, when the decomposition of organic matter run well, potassium concentration will increase accordingly.

CONCLUSIONS

The result of the study shows that water contents of the mixture are not significantly influencing the change of pH and temperature of composting process. However, the highest change of the pH and temperature were obtained from water content of 40%. Furthermore, the result of the study shows that CN_3 provides significant effect on nitrogen and phosphorus contents of liquid organic fertilizer in comparison to CN_1, but not on CN_2. Finally, only CN_3 provides significant effect on potassium content of the fertilizer.

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