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Effects of the Different Loading Characters of Cattle Manure as Inoculum Towards the Composting Process of Coconut Pulp Waste

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ABSTRACT

The current study evaluated the effects of loading characters of cattle manure as inocula on the composting of coconut pulp residue. A series of experiments were carried out to evaluate characteristics of compost generated from the different treatments. Results showed that total organic carbon of both finished compost T1 (56%) and T2 (57%) were close to that of the normal compost. The results of the study showed that that composts T2 had higher total nitrogen content (1.53%) than that of compost T1 which contained around 1.34%, and both are still in the normal range of total nitrogen of the finished composts. The electrical conductivity of compost T2 (625 mS/m) was about two times higher than that of compost T1 (296 mS/m) suggesting that the compost T1 was feasible used as a fertilizer in agriculture.

1. INTRODUCTION

Application of waste management in developing countries still becomes a major challenge. This is because the countries still focus on coping with some essential issues including over-population, lack of energy and food stocks, limited funding and human resources [1]. The quantity of organic solid and liquid wastes produced by people is closely related with an increase of population [2, 3]. The rapid population growth in low and middle-income countries has been linked to the unavailability of proper infrastructures to treat the organic solid waste effectively [1]. If tons of organic wastes are not properly treated, they would pollute the environment [4, 5].

Landfilling is a common practice applied for managing organic solid wastes especially domestic and municipal solid wastes. Uncontrolled biodegradation of deposited organic materials in a landfill may generate toxic liquid (i.e. land fill leachate) and potent greenhouse gas, such as methane [6]. Biological waste processing would be a potential method applied for treating organic wastes since the process would be costly effective and environmentally friendly [7, 8]. The composting process of organic waste would generate organic fertilizer as an economically valuable product [9], which can be used for soil emulsifier and finally could reduce the dependency of chemical fertilizer usage in an agricultural field.

Composting process is a natural process involving decomposition of organic materials into soil conditioner with the presence of microorganisms [10, 11]. As an established solid waste treatment technology, the composting process is considered as a green as well as cheap practice for sustainably treat and manage the organic wastes [12].

The current study focuses on the comparison of two-different methods of inoculum loaded into the aerobic digester including shock load and stepwise or gradual loading process. Besides, the study would investigate the characteristics of composts resulted from the two-composting processes including the assessment of performances and nutrient recovery.

2. MATERIAL AND METHOD

2.1 Material preparation

Coconut pulp residue used for the experiment was collected from several restaurants situated in Banda Aceh, Indonesia. The percentage of moisture content of coconut pulp residues used for the composting process was about 64 ± 0.35% (wet basis).

Cattle manure used as an inoculum for the fermentation of the coconut pulp during the composting process was obtained from the cattle unit farm at Limpok, Aceh Besar. To assess the physical and chemical characteristics of materials used for the composting process, coconut pulp residues and cattle manure were analyzed for pH and alkalinity, carbon and nitrogen content, electrical conductivity, and other parameters as presented in Table 1.

Table 1. Physico-chemical properties of substrates

Parameters	Unit	Cattle manure	Coconut Pulp Residue
NH_4^+-N	mg·l^{-1}	15 ± 0.5	22 ± 0.5
PO_4	mg·l^{-1}	2.5 ± 0.15	2.5 ± 0.12
K	mg·l^{-1}	450 ± 0.05	500 ± 0.05
Total dissolved solids	mg·l^{-1}	32.7 ± 0.2	2300 ± 0.01
Electrical conductivity	mS	65.4 ± 0.1	457 ± 0.01
Salinity	mg·l^{-1}	34.3 ± 0.1	2.3 ± 0.1
ORP	mV	65.7 ± 0.2	150.3 ± 0.1
pH	-	7.83 ± 0.01	4.57 ± 0.01
Alkalinity	mg·l^{-1}	793.5 ± 0.15	848.84 ± 0.01
Organic matter content	%	40.71 ± 0.015	87.78 ± 0.02
Total Organic Carbon	%	48.43 ± 0.01	57.85 ± 0.01
Solid content	%	0.01 ± 0.002	35.61 ± 0.01
Moisture content	%	99.99 ± 0.001	64.4± 0.02

2.2 Experimental design and procedures

The tests were conducted at the Laboratory of Post Harvest Technology and Bioprocess, Department of Agricultural Engineering, Syiah Kuala University. The composting process was carried out by using bioreactors with the working volume of 150 m^3. The bioreactor was steadily agitated at around 155 ± 0.5 rpm. Cattle manure used as inocula for the composting process of coconut pulp was transferred to the main digester by using electrical nozzle. The inoculum introduced to the digester would be differentiated into two treatments. The first treatment (T1) was conducted in which the inoculum was gradually added to the digester during the composting process. The second treatment (T2) was carried out in which the inoculum was fully added at the beginning process of composting or considered as a shock-load of inoculum added to the reactor.

The performance of the composting process and the characteristics of the finished composts would be evaluated by different loadings of inoculum including gradual loading and shock loads. During the composting process, the temperature operation was not maintained, and the temperature process was carried out under the ambient temperature (30 ± 3°C). This was carried out to cut the production cost due to the use of external energy, and thereby would generate the sustainable composting processes [13].

Each composting process was loaded with 20 kg of coconut pulp and 25% (W/V) inoculum. The total of inoculum loaded to the reactor containing coconut pulp residues as substrate was about 5 liter. The duration of the composting process was 7 days. The first composting process, the coconut pulp composted was gradually added 1 liter of the inoculum while the second composting process the coconut pulp was directly loaded of 5 liter inoculum. After the composting process, samples of each composting process were taken for assessing the characteristics of the produced composts.

2.3 Analytical methods

Samples taken were analyzed for composting parameters including pH, alkalinity, electrical conductivity (EC), salinity, total dissolved solids (TDS), oxidation reduction potential (ORP), solid content, moisture content (MC), organic content (OC), total ammonium nitrogen (NH_4-N), total nitrogen (TN), total organic carbon (TOC), phosphate (PO_4), and potassium (K). To evaluate the effectiveness of composting process of coconut pulp, the carbon to nitrogen (C/N) ratio of each inoculum loading method was included in the measurement. All analysis methods were conducted based on the standard methods [14].

3. RESULTS AND DISCUSSION

The composting process was carried out using prototype of bioreactor that was continuously agitated indicating that the process of decomposition of substrate would be more effective. Study mentioned the composting process has been typically characterized by physico-chemical parameters [15]. In this current study, the measurements of physico-chemical characteristics of the substrates and inoculum were carried out to evaluate the performance of composting process and the quality of the compost produced (Table 1).

Results showed that the acidity represented in pH level of the coconut pulp residues was too acidic (pH < 5.0) while of pH of the cattle manure used as inoculum was quite well that was close to the neutral level (pH 7.8). Li et al. [16] found that the optimum pH for the composting process should be between 7 and 8. Some studies mentioned that microorganisms involved in the composting process would work best under neutral to acidic condition in which pH of the mixture should be in the range between 5.5 and 8 [17, 18]. However, some studies mentioned that the composting process and decomposition would be more effective when pH was under the neutral level [19-21]. This suggested that the use of cattle manure having a neutral pH as an inoculum for the composting of coconut pulp residues would feasible.

As presented in Table 2, results of the current study revealed that total organic carbon of compost obtained from the gradual addition of inoculum was slightly lower (56.3%) than that of the compost of the shock-loaded inoculum (57.24%). The results quite close to the study revealed that organic matter of compost normally contains about 54% of organic carbon [22]. The organic matter contents of the two finished composts were around 73% (T1) and 57% (T2). The results are somewhat in agreement with the study revealing that the organic matter content of finished compost should be in the range between 30% and 70% while for most compost uses the organic matter content of the compost should be in the range 50 to 60% [23, 24]. This suggested that the compost produced from this process was quite optimal as well as feasible for the land application. Also, the compost produced would be used for promoting the soil health and crop production [25].

Table 2. Compost characteristics from different types of inoculum loading

Parameters	Unit	Treatments	
		T1	T2
NH_4^+-N	$mg \cdot l^{-1}$	15.3 ± 0.01	17.5 ± 0.01
Total dissolved solids	$mg \cdot l^{-1}$	1490 ± 0.1	3140 ± 0.2
Salinity	$mg \cdot l^{-1}$	1.5 ± 0.01	3.2 ± 0.1
ORP	mV	100.5 ± 0.02	110.4 ± 0.15
Phosphate	$mg \cdot l^{-1}$	10 ± 0.1	12 ± 0.1
Alkalinity	$mg \cdot l^{-1}$	396.74 ± 0.005	598.4 ± 0.03
Organic content	%	96.55 ± 0.015	98.46 ± 0.01
Total organic carbon (TOC)	%	56.13 ± 0.01	57.24 ± 0.002
Solid content	%	46.15 ± 0.005	23.61 ± 0.01
Moisture content	%	53.83 ± 0.011	76.4 ± 0.15

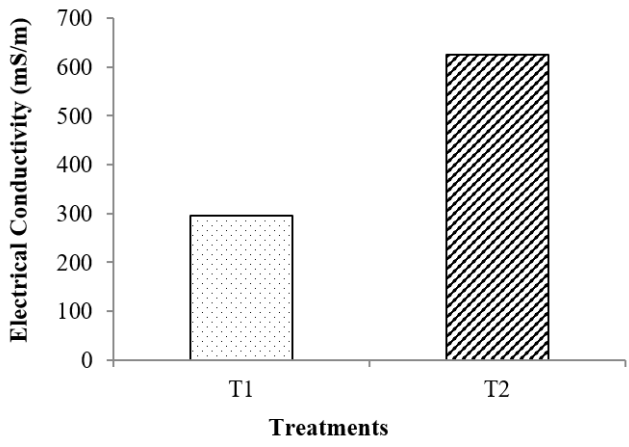

Figure 1. Electrical conductivity of composts obtained from different loading types of inoculum

As depicted in Figure 1, the results of the present study showed that the electrical conductivity of compost T2 (625 mS/m) was about two times higher than that of compost T1 (296 mS/m). High electrical conductivity in compost T2 indicated that the compost contained a significant amount of soluble salt content [26, 27]. This reaffirmed with the salinity content of compost T2 (110 mg/L), which was higher than that of the compost T1 (100 mg/L). This showed that the addition of high amount of cattle manure as an inoculum to the composting digester would enhance the soluble salt content in the resulted compost. Also, electrical conductivity in compost T2 was extremely higher than that of the typical compost used as fertilizer in agriculture, which was between 200 and 350 mS/m [28, 29]. This suggested that compost T1 was quite readily suitable used as an organic fertilizer in agriculture uses.

The results showed that composts T2 generated slightly higher potassium (305 mg/L of K) than that of compost T1 which contained around 300 mg/L of potassium. This agreed with study by Basak [30] revealing that a significant amount of potassium released during the composting process. Further, the current study revealed that different treatments of inoculum added to the reactors during the composting process did not significantly affect the generation of potassium of the composts produced from the coconut pulp waste (Figure 2).

As potassium is one of the plant macronutrients, the compost produced from this process still would be potential to be used as an alternative fertilizer to cut the dependency of chemical fertilizers. Study by Andrews et al. [25] revealed that potassium ions may easily solubilize from plant materials into soil solution due to its high mobility as a primarily unbound monoatomic cation in tissues of plant. Basak [30] found that the use of potassium-enriched compost significantly enhanced the availability of potassium in a potassium-deficient soil. Hence, the produced compost would be potential to be utilized as an effective soil conditioner.

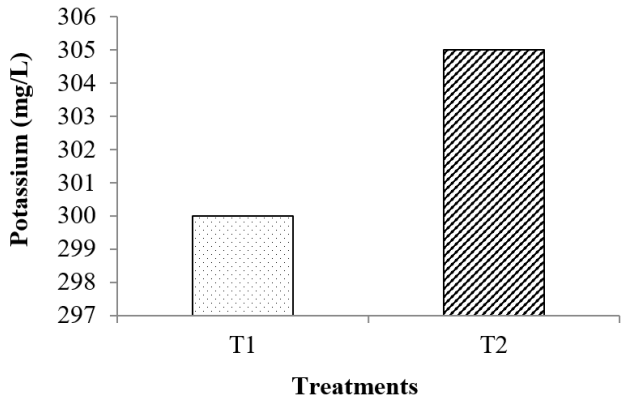

Figure 2. Potassium of composts obtained from different loading types of inoculum

The results of the study showed that that composts T2 had higher total nitrogen content (1.53%) than that of compost T1 which contained around 1.34% (Figure 3). This result agreed with the study finding that total nitrogen of finished compost typically ranged from 0.5 to 2.5% [31]. As presented in Table 2, the available nitrogen used for land applications represented in ammonium content was higher in compost T2 (18 mg/L of NH_4^+-N) than that of compost T1 (15 mg/L of NH_4^+-N). This suggested that shock-loading of cattle manure as inoculum into the digester at the beginning of the composting process would effectively increase nitrogen content of the compost. Study revealed that the major sources of nitrogen for plants mostly had been recommended to be ammonium and nitrate [32]. This suggested that the finished compost would be feasible used as a bio-fertilizer as it contains nitrogen, which is readily available for plants.

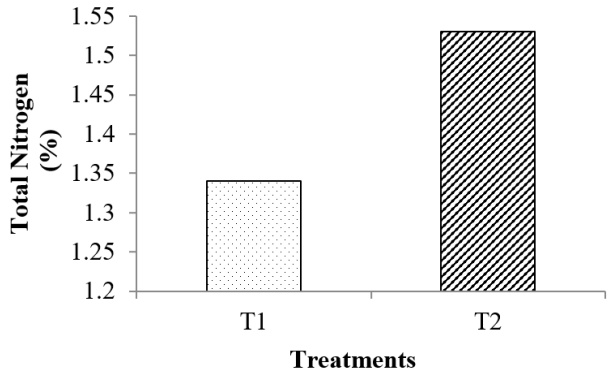

Figure 3. Total nitrogen of composts obtained from different loading types of inoculum

As depicted in Figure 4, the results showed that C/N ratio of compost T1 (42) was higher than that of compost T2 (37). Study revealed that finished compost with high C/N ratio tends to immobilize nitrogen if it is applied to the soil while compost with low C/N ratio may mineralize organic nitrogen to inorganic nitrogen, which is available for plants [33]. This indicated that the duration of composting process should be longer in order to decrease the C/N ratio of the finished compost. This is because C/N ratio of the mixture prior to the composting process was above 25 (30.05) suggesting that the process requires more time to lower the level of C/N ratio. Besides, C/N ratio below 25 would be low risk and high quality for land application [34].

The results of the study revealed that pH of compost T1 (5.52) was higher than that of compost T2 (5.06) as shown in Figure 5. The results are somewhat close to the study revealing that most finished compost would have pH values in the level of 5.0 to 8.5 [31]. However, the recommended pH values of the compost should be in the range 5.5 and 8.5 [35]. Hence, the result suggested that pH value of compost T1 is within in the recommended range. Besides, study found that fungal decomposers preferred pH ranging from 5.5 to 8.0 [36]. The acidic conditions would be best favorable for the growth of fungi, and also may help degrade lignin and cellulose during the decomposition process [37-39].

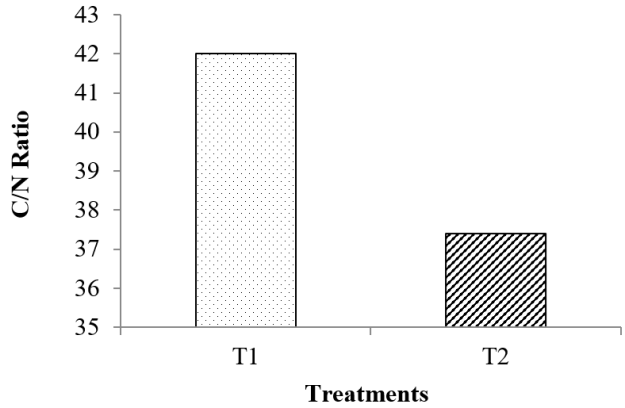

Figure 4. C/N ratio of composts obtained from different loading types of inoculum

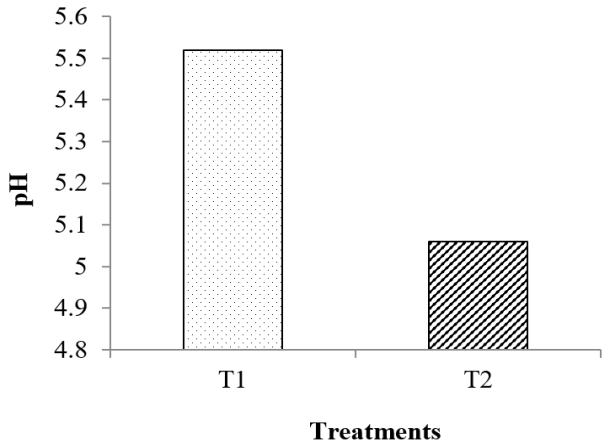

Figure 5. pH of composts from different loading types of inoculum

4. CONCLUSIONS

The study found that the inoculum of cattle manure that was gradually added to the mixture of compost materials during the composting process would generate compost that have more suitable for land application since it had a feasible electrical conductivity (300 mS/m) for agriculture uses. The study also found that, the compost generated from the gradual addition of inoculum would have a suitable pH (5.5) for the growth of fungal decomposer. This suggested that the compost produced from the coconut pulp waste inoculated with cattle manure under the gradual and shock load treatments of inoculum was quite feasible to be applied to the land for supporting plant growth and crop production.

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