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Effect of green waste pretreatment by sodium hydroxide and biomass fly ash on composting process

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ABSTRACT

Green waste contains a major portion of lignocellulose which is hard to be decomposed. The objective of this study was to determine the effect of alkaline pretreatment using sodium hydroxide (NaOH) and biomass fly ash for the composting of *Samanea saman*. The experimental detail consists of seven runs, that is, control; 1%, 2%, and 3% NaOH treatments; and 6.2%, 12.4%, and 12.4% biomass fly ash treatments. The pretreatment was conducted by mixing of NaOH and fly ash with green waste for 2 d and transferring the mixture to be composted in 55-L polystyrene thermo cooler boxes. The composting was performed for 105 d. The temperature was recorded daily and the compost characteristics were analyzed every 7–14 d. The highest maximum temperature was found in the NaOH treatment. However, the mean temperatures of all the experiments were not significantly different. The initial C/N ratios of the waste for all the runs ranged from 51.11 to 54.90 before continually decreasing/increasing to be in the range of 42.64–65.28 at the end of the experiment. The high C/N ratio of the end compost in the alkaline treatment might be attributed to the high initial C/N ratio and the N loss that resulted from the high pH of the compost material. The results of the lignin mass reduction show that 1–2% NaOH and 6.2% fly ash treatments can reduce lignin 2 times better than the control. However, higher doses of alkaline matter can increase the nitrogen loss due to volatilization of ammonia in the higher pH condition. In order to enhance the decomposition of green waste and minimize the nitrogen loss in the composting process, the pretreatment by 6.2% of fly ash can be selected.

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1. Introduction

Green waste represents a significant proportion of municipal solid waste (MSW) which is currently handled by the municipal authority in Thailand. The proportion of green waste in the MSW, as recorded by the Pollution Control Department, Thailand, is in the range of 3–18.5% (PCD, 2014). At present, most green waste is disposed to landfills or subjected to open-burning in suburbs and rural areas. Decomposition of organic waste under anaerobic conditions in landfills produces greenhouse gases, namely methane (CH₄) and carbon dioxide (CO₂). The comparative impact of CH₄ on climate change is 25 times greater than that of CO₂ over a 100-year period (USEPA, 2016). CH₄ is considered to be a significant contributor to global warming and control of CH₄ emissions from landfills is of great importance. Green waste is usually open-burned in suburbs and rural areas in many developing countries. Various

gases, such as nitrogen oxides, volatile organic compounds, carbon monoxide, and particle pollution, are released into the environment (Kannan et al., 2004). Dioxins are also emitted from incineration of fallen leaf (Katami et al., 2004) and backyard burning (Wevers et al., 2004). Green waste should be treated properly. Life cycle assessment studies concluded that composting of organic waste has lesser environmental impact as compared to other methods of disposals, such as landfilling and incineration (Saer et al., 2013). In addition, composting is widely regarded as a clean and sustainable method to manage organic waste (Lim et al., 2016). Composting is a viable alternative method for managing green waste. In most cities in the developed countries, such as Germany and Australia, green waste is collected separately from other kinds of waste and is mechanically shredded and then composted, either alone or with other organic waste. Green waste is mainly lignocellulosic biomass. The main component of lignocellulose is cellulose, a linked chain of glucose molecules. Hydrogen bonds between the different layers of the polysaccharides contribute to the resistance of crystalline cellulose to degradation. Hemicellulose, the second most abundant component of lignocellulose, is composed of

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various 5-carbon and 6-carbon sugars. Lignin is composed of three major phenolic components and is synthesized by the polymerization of these components, and their ratio within the polymer varies between different plants, wood tissues, and cell wall layers (Rubin, 2008). Lignocellulose is difficult to degrade; therefore, the composting period required for green plant waste stabilization is longer than that for other organic waste. The biodegradability of lignocellulose can be enhanced by pretreatment of lignocellulosic materials, including by removing the lignin, loosening the cellulose structure (Zhang and Liu, 2005), and increasing the effective contact area of the cellulose with the microorganisms (Kim et al., 2008). There are numerous pretreatment techniques for the delignification of biomass materials, and alkaline pretreatment is among the most common ones due to its low cost (Behera et al., 2014). Sun et al. (2011) revealed that alkaline treatment can reduce lignin and cellulose, and increase hemicelluloses by partially breaking the chemical bond between lignin and cellulose.

Recently, increasing use of biomass power plants has significantly increased the amount of fly ash in Thailand. Fly ash can be applied as an amendment in composting due to its known capability to buffer pH (Kurola et al., 2011) and reduce compost malodors (Koivula et al., 2004). Fly ash contains several minerals needed for plant growth and has been used widely for soil amendment (Jala and Goyal, 2006). Karnchanawong et al. (2014) found that there was no effect from the addition of biomass fly ash for up to 12% of the compost mix on the composting process performance and that there was no indication of an increase in the ammonia volatilization from the compost mixes. In addition, it was found out that fly ash can neutralize acidic soil and increase vegetable yield (Karnchanawong and Najarus, 2014). Another study conducted by Juárez et al. (2015) also illustrated that the addition of up to 15% of wood ash to biowaste did not negatively affect the composting process; however, composts with higher ash amendment (>12%) did not comply with the highest quality standards established by the Austrian Compost Ordinance (FLG II Nr. 292/2001) in terms of Cd level.

Previous studies have focused on the fermentation of agricultural lignocellulosic stalks pretreated by alkaline for ethanol products such as biobutanol (Cai et al., 2016) and acetone butanol ethanol (Gao and Rehmann, 2014). There has been very little research reported on the effects of alkaline pretreatment on green waste composting. In addition, most fly ash has alkaline properties and may be used as an alkaline agent to pretreat the lignocellulosic material before composting. This study was conducted to determine the effect of alkaline pretreatment, using NaOH and biomass fly ash, on green waste composting.

2. Materials and methods

2.1. Composting process

The composting was conducted in seven 55 L polystyrene thermo cooler boxes. The internal and external, and the interior dimensions were 500 × 500 × 300 mm and 450 × 450 × 27 mm.

Table 1
Alkaline agent used in the experiments.

Run	Alkaline agent		Basicity as pure NaOH
1	Control (C)	None	–
2	NaOH 1%	Industrial grade NaOH	0.88%
3	NaOH 2%		1.76%
4	NaOH 3%		2.64%
5	Fly ash 6.2%	Biomass fly ash	0.88%
6	Fly ash 12.4%		1.76%
7	Fly ash 18.6%		2.64%

The *Samanea saman* tree green waste inclusive of leaf and small branch (10 kg) was collected from Chiang Mai University campus. The waste was shredded to less than 25 mm by knife mill. NaOH and biomass fly ash were selected to be the alkaline materials to pretreat the green waste. The alkaline agents used in this study were NaOH (industrial grade, CAS:1310-73-2, AGC Chemicals, Thailand, with a pH of 13.45) and biomass fly ash (with a pH of 10.35) supplied by the Sahacogen Green Biomass Power Plant located in the Lamphun province, Thailand. The biomass materials used in the power plant were wood chips, rice husk, corn cob, and wood shavings. The experimental detail consists of seven runs, as presented in Table 1. The initial value of the C/N ratio of the green waste was around 50/1. The pretreatment was conducted by mixing each alkaline material and water, and then adding the mixture to the green waste in a 70 L polyethylene bin for 2 d. The amounts of NaOH and biomass fly ash added into the green waste were 1%, 2%, and 3% and 6.2%, 12.4%, and 18.6% (wt/wt of green waste wet weight), and these had the same basicity of pure NaOH at 0.88%, 1.76%, and 2.64% (see Table 1). The water was added to the mixtures in order to make the moisture content around 80%. After that, the waste was spread on the floor for air-drying for 1 d and composted in the 55-L polystyrene thermo cooler boxes. The composting process was conducted at an indoor ambient temperature which was in the range of 20.3–29.4 °C. Each experiment was performed in duplicate. The composting was performed for 105 d, and the turning was manually conducted once a day for around 5 min in order to aerate and mix the compost material. The moisture content during the composting period was controlled to be in the range of 50–70% (Cronjé et al., 2004) by spraying water after analysis of the compost mix moisture content using the gravimetric method.

2.2. Sample analysis

The temperature at the middle part of the waste layer in each box was recorded daily using a digital thermometer. Six subsamples of the compost were randomly collected from two equidistant cross sections and three parts of each box. Each sample was taken by mixing the six subsamples and then analyzed for pH, electrical conductivity (EC), moisture content, C, N, volatile solids (VS), lignocellulose, and lignin. The analyses were performed once a week except the analyses for lignocellulose and lignin which were conducted once every 2 weeks. After 105 d, the compost from each box was removed and weighed to determine the total mass reduction. The pH and EC of the compost were determined by measuring the slurry in the ratio of 1:10 of compost to water, using a Horiba F-21 pH meter (Kyoto, Japan). The organic carbon content was determined using a method based on Walkley and Black (Walkley and Black, 1934). The nitrogen content was analyzed by a modified micro-Kjeldahl procedure using a 2100 Kjeltac distillation unit (FOSS, Hillerød, Denmark), according to the AOAC methods (AOAC, 2005). The moisture content and the VS were determined using a gravimetric method (APHA, 1997). The lignin and lignocellulose were analyzed using a detergent method based on AOAC (AOAC, 2005).

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