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Torrefaction of Municipal Solid Waste in Malaysia

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Abstract

Municipal solid waste (MSW) disposal is one of the main issues towards sustainable development in Malaysia. Current practices for MSW disposal such as landfilling and incineration poses a serious problems on the environment and health. Therefore a significant efforts have been made to utilize MSW for energy source by employing gasification process. However, the MSW is characterized by its high moisture content and low high heating value (HHV) which lowering the energy efficiency. In order to overcome this problems, torrefaction can be used as pretreatment method to remove the moisture content and upgrading MSW properties. The objective of this work is to study the effects of torrefaction temperatures ranging from 240 to 330°C for residence time of 30 minutes on two types of MSW namely food waste and wood waste. The torrefied MSWs are characterized in terms of ultimate analysis, proximate analysis and HHV. The mass and energy yields are also performed for both MSW. Based on the torrefaction, it was found that both food waste and wood waste show an increment on the weight percentage of C contents and decrement on the weight percentage of H and O content which resulting into reduce O/C ratio as the temperature is increased. The HHV for both food waste and wood waste are also increased after torrefaction between 240 and 330°C. The mass yield and energy yield were found to decrease with an increase in the torrefaction temperature. This suggests that torrefaction can be used as an effective MSW pretreatment and the torrefied MSW is more suitable to be used as fuel in gasification process.

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Keywords: Torrefaction; Municipal solid waste; Food waste; Wood waste; Ultimate analysis; Proximate analysis

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1. Introduction

The Malaysian population has been increasing from 23.49 to 30.65 million between 2000 and 2015 [1]. In line with the rapid population growth, the generation of municipal solid waste (MSW) also increases. Based on MSW generation study conducted in Malaysia, the total daily MSW generation was 29,711 tonne/day in 2012 and an overall of 36,165 tonne/day of MSW has been projected to be hit by 2020 [2]. Due to the tremendous MSW generation rate, the MSW disposal becomes one of the main issues affecting environmental and sustainable development. Current practice exploits landfilling as the most common method for MSW disposal and most of the landfill sites in Malaysia are open dumping areas which pose serious environmental threats such as a large scale contamination of soil, water and air. Another common practice to dispose MSW is by using incineration technology. Theoretically incineration technology is the controlled combustion of waste with the recovery of heat to produce steam that in turn produces power through steam turbines. However emissions from incinerator can produce a wide variety of pollutants such as heavy metal, dioxins and furans which are detrimental to human health [3].

Alternatively gasification process can be adopted to overcome MSW disposal problem. Gasification involves partial combustion or oxidation of biomass to produce synthesis gas and ash at high temperatures (>800°C) in the presence of gasifying agent such as air or steam. The synthesis gas consists of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2) and methane (CH_4) and after cleaning up can be used for heat and gas providing, electricity generation and chemical synthesis [3]. The MSW utilization using gasification will reduce significant amount of waste, preserve landfill space and an alternative for advanced thermal treatment application. Many attempts have been made to investigate the production of synthesis gas from various types of biomass [4-5]. Although hydrogen gas can be produced from those gasifiers, there is a concern on the low energy efficiency and low fuel quality [4]. This is due to the fact that raw biomass contains high moisture content between 40 – 80%, low bulk density, high O/C ratio and relatively low calorific value. Due to the high moisture content, the raw biomass is classified as hygroscopic in nature because moisture can be absorbed into the cell walls and hydrogen bonded to the hydroxyl groups of the cell wall components. Due to the hygroscopic nature of raw biomass, the gasification rate become slow and as consequence the conversion efficiency become low. As consequence, high energy is needed to remove the moisture content due to the drying during gasification process and in the end high consumption of energy is required. In addition, due to the low carbon content (high O/C ratio) and low calorific value, the amounts of synthesis gas production particularly hydrogen gas is relatively low which contributing to the low cold gas energy and exergy efficiencies [5].

One of the ways to improve the fuel quality is by using torrefaction method. Torrefaction is a pretreatment method to upgrade raw biomass to a refined fuel with improved properties such as higher heating value and carbon content [6-8]. Torrefaction is usually carried out at temperature in the range of 200-300 °C for residence time between 30-60 min in an inert environment at atmospheric pressure [6]. As a result of torrefaction, biomass exhibits brittle behaviour and a reduction in mechanical strength thus eliminating poor grindability problem of raw biomass. Besides, torrefaction increase energy yield of torrefied biomass due to the increase of carbon contain. It also reduces the moisture content and hemicellulose content in biomass so that the shelf life of biomass is increased as no biodegradation occur during the storage [6]. Because of these improved properties, the value in terms of carbon content and heating value of the torrified biomass as a fuel is significantly higher than the raw biomass. Therefore the objective of this work is to perform torrefaction experiment using MSW at various temperatures between 240-330 °C under a nitrogen atmosphere for 30 min. In this study two main types of MSW are used namely food waste and wood waste considering both wastes are non-recyclable and the main contributor of the MSW in Malaysia. The ultimate analysis, proximate analysis and high heating value (HHV) are also measured and compared for raw and torrefied MSW. The effect of different torrefaction temperature on the mass yield and energy yield is also investigated.