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Bio-oils from microwave pyrolysis of agricultural wastes

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ABSTRACT

Pyrolysis of palm kernel shell (PK), wood chips (WC) and sago wastes (SW) was performed on microwave irradiation at different heating time, at moderate temperature 250–390 °C. Samples were placed in quartz reactor and subjected to microwave heating in inert atmosphere to afford bio-oils (PKO, WCO and SWO). The highest calorific values recorded are 27.19 MJ/kg, 25.99 MJ/kg, and 21.99 MJ/kg for PKO, WCO and SWO. FTIR spectroscopy showed the presence of functional groups such as phenol, alcohols, ketones, aldehydes and carboxylic acids. The GCMS showed that PKO, WCO and SWO consist of significant quantities of potentially high value hydrocarbons such as monoaromatic hydrocarbons and phenolic compounds. Importantly, the bio-oils do not contain carcinogenic polyaromatic hydrocarbons (PAH). Upon further refining, the bio-oils have a potential as valuable source for fuel or chemical feedstocks.

1. Introduction

Pyrolysis of biomass has received increasing attention in the last decades. The production of bio-oil from pyrolysis of biomass is gaining interest due to its higher energy density as well as easy storage and transportation. Bio-oil can become an alternative for fuel or diesel in static applications for electricity generation [1].

Bio-oil is also known as pyrolysis oil or pyrolysis liquid. It is usually in the form of dark brown organic liquids [2] with comparable heating values with oxygenated fuels like methanol and ethanol [3]. It has water content ca 15–30 wt.%, which originated from the moisture contained in raw materials and also dehydration during pyrolysis and storage [4].

Bio-oil obtained from the pyrolysis of biomass consists of oxygenated hydrocarbon complex mixture with molecules of different sizes which results from depolymerization and fragmentation of cellulose, hemicelluloses and lignin [4]. Bio-oil derived from pyrolysis contains acids, alcohols, aldehydes, ethers, esters, ketones, sugars, phenols, guaicols, syringols, furans, lignin derived phenols and extractable terpene with multifunctional groups and several species of oxygenated organics [5,6]. The presence of aromatic and oxygenated compounds was associated with cellulose and hemicelluloses content of the feedstock [7].

Bio-oils produced from microwave pyrolysis show some differences in their components compared to conventional pyrolysis. Microwave and conventional pyrolysis of pine sawdust, for instance, showed similarity in content but some additional compounds such as toluene, 3-penten-2-one, propanoic acid, and cyclopentanone, were detected from microwave pyrolysis [8].

Microwave pyrolysis generates less polycyclic aromatic hydrocarbons (PAHs) compared to bio-oil obtained from electrical furnace [9]. This is due to the fact that during microwave pyrolysis, the samples is directly heated and reached high temperature in a short time while the reactor wall remains at a lower temperature than the bulk sample. Lower temperature inhibits secondary reactions of pyrolysis products, thus produced high quality product with less PAH [9,10]. However, significant concentrations of PAH were reported when the input power increased from 300 W to 900 W [11].

In this study, we report on the microwave pyrolysis of agricultural wastes concerned in Malaysia such as palm kernel shell (PK), wood chips (WC) and sago wastes (SW) for production of bio-oil under different heating time. The calorific value of the palm kernel shell bio-oil (PKO), wood chip bio-oil (WCO) and sago wastes bio-oil (SWO) was determined to evaluate their potential as a liquid-fuel.

2. Experimental

2.1. Material

Bio-oil used in this study was produced from microwave pyrolysis of PK, WC and SW using a modified household microwave with input power 1000 W and frequency of 2450 MHz (SHARP R-958A). 10 g of sample was placed in a quartz chamber and purged with nitrogen gas at 500 ml/min in 30 min, followed by pyrolysis at 3 min, 5 min, and 7 min for PK and WC, while SW was treated only for 2, 3 and 4 min. At longer treatment time of SW, bio-oil produced was found very viscous, sticky and hard to be collected. This could be attributed to the softer

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