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Oil palm waste: An abundant and promising feedstock for microwave pyrolysis conversion into good quality biochar with potential multi-applications

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Highlights:

- Oil palm waste has high carbon content for pyrolysis conversion into biochar.
- Microwave pyrolysis produces 38 wt% of biochar with high chemical resistance.
- Biochar has high surface area, porosity, carbon, and low ash and moisture.
- Biochar shows potential for use in wastewater treatment, agriculture and energy.

Abstract

Oil palm waste (OPW), comprising mainly of empty fruit bunch, mesocarp fiber, frond, trunk, and palm kernel shell generated from palm oil industry, was collected, characterized, and then pyrolyzed to evaluate their potential to be converted into biochar with desirable properties for use in multi-applications. The OPW was detected to have considerable amounts of carbon (43–51 wt%) and fixed carbon (30–39 wt%), showing potential to be converted into carbon-rich biochar. Microwave pyrolysis of palm kernel shell as the selected OPW produced a biochar with zero sulphur content and high heating value (23 – 26 MJ/kg) that is nearly comparable to conventional coal, thus indicating its potential as an eco-friendly solid fuel. The biochar obtained was also showed low moisture (< 3 wt%) and ash (3 wt%), and a highly porous structure with high BET surface area (210 m^2/g), indicating the presence of many adsorption sites and thus showing desirable characteristics for potential use as pollutant adsorbent in wastewater treatment, or bio-fertilizer to absorb nutrient and promote plant growth. Our results demonstrate that OPW is a biowaste that shows exceptional promise to be transformed into high-grade biochar rather than simply disposed by landfilling or burned as low-grade fuel in boiler.

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Keywords: Oil palm waste, microwave pyrolysis, biochar, adsorbent, bio-fertilizer, solid fuel

Introduction

Oil palm plantations occupy the largest sector of agriculture in Malaysia with approximately 5.7 million hectares of plantation area in 2016 (MPOB, 2017). The subsequent processing to produce palm oil inadvertently produces great amount of oil palm wastes (OPW) that generally comprise of 15% of mesocarp fibres (MF), 6% of palm kernel shells (PKS), and 23% of empty fruit bunches (EFB) in one ton of fresh fruit bunch (FFB) of oil palm (Loh, 2016; Omar et al., 2011). According to Malaysia Palm Oil Board (MPOB) (Board, 2017), the total production of crude palm oil (CPO) in Malaysia was 3.4 million tonnes in 2016, hence about 25.5 million tonnes of OPW were generated since 75 wt% of the solid wastes were produced from 10 wt% of CPO.

The majority of OPW (e.g. PKS and MF) are currently burned in boiler to generate steam for sterilization of fresh fruit bunch, however this method could lead to air pollution by releasing flue gases containing ash, CO, and NO_x into the atmosphere (Okoroigwe et al., 2013). OPW is also used as combustion feedstock for electricity generation in some palm oil mills, which leads to production of undesirable ash (Awalludin et al., 2015). It is thus thought that an alternative method should be developed by transforming OPW into value-added materials such as biochar or activated carbon to improve the recovery of OPW and divert these wastes from landfill or being a source of air pollution.

Pyrolysis, a thermal decomposition process under an inert environment, shows potential as an environmental friendly method to treat OPW (Lam et al., 2016a). Combustion of waste can release significant amounts of greenhouse gases such as carbon dioxide (CO_2), whereas pyrolysis method can limit the production of greenhouse gases and decompose the waste to produce potentially useful products comprising of solid biochar, liquid bio-oil and