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Pyrolysis of oil palm empty fruit bunch biomass pellets using multimode microwave irradiation

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HIGHLIGHTS

- Ball lightnings were observed during microwave (MW) pyrolysis of biomass pellets.
- EFB pellets were pyrolysed in a multimode MW system even in absence of MW absorber.
- Biomass to MW absorber ratio affected the temperature profiles of the pyrolysis.
- The properties of bio-oil and bio-char were also found to depend on this ratio.

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ABSTRACT

Oil palm empty fruit bunch pellets were subjected to pyrolysis in a multimode microwave (MW) system (1 kW and 2.45 GHz frequency) with and without the MW absorber, activated carbon. The ratio of biomass to MW absorber not only affected the temperature profiles of the EFB but also pyrolysis products such as bio-oil, char, and gas. The highest bio-oil yield of about 21 wt.% was obtained with 25% MW absorber. The bio-oil consisted of phenolic compounds of about 60–70 area% as detected by GC–MS and confirmed by FT-IR analysis. Ball lightning (plasma arc) occurred due to residual palm oil in the EFB biomass without using an MW absorber. The bio-char can be utilized as potential alternative fuel because of its heating value (25 MJ/kg).

1. Introduction

Millions of tons of oil palm biomass in the form of shells, fibers and empty fruit bunches are generated every year by oil palm mills. Conversion of these biomass into energy and value added products has been already investigated (Abdullah and Bridgwater, 2006; Idris et al., 2010; Razuan et al., 2010; Sumathi et al., 2008; Sulaiman and Abdullah, 2011) and one of the conversion is to pyrolyse biomass into bio-fuels (bio-oil, bio-char and product gas). Bench scale fast pyrolysis system for empty fruit bunch (EFB) biomass have already been developed (Abdullah and Bridgwater, 2006; Abdullah and Gerhauser, 2008). Sulaiman and Abdullah (2011) attempted to optimize the pyrolysis products obtained from EFBs by considering parameters such as reactor temperature, residence time of the particles and particle size in a fluidized bed system. The authors obtained the highest bio-oil yield at a temperature of about 450 °C and at residence time of 1.03 s. Azizan et al. (2009) reported a temperature of about 500 °C and a reaction time of about 3 h as optimum for production of bio-oil from EFB in a fixed bed reactor.

Conventional reactor system such as fixed and fluidized bed reactors require finely ground feedstock with moisture content of less than 8 wt.% to achieve high heat and mass transfer rates. In order to supply continuous heat to the reactor external heating systems such as gas pre-heater and electrical heaters are usually employed. These heating systems work on conduction and convection heat transfer principles that might restrict a rapid heating rate of the biomass. Furthermore, undesired secondary reactions are caused due to surface heating of particles (Miura et al., 2004). In order to overcome the above problems microwaves (MW) were used to pyrolyse EFB pellets. MW pyrolysis of different biomasses has been already investigated, including that of fir/pine wood sawdust (Chen et al., 2008), corn stover and aspen (Wan et al., 2009), rice straw (Huang et al., 2008, 2010), wheat straw (Budarin et al., 2009), oil palm biomass (Salema and Ani, 2011), microalgae (Hu et al., 2012), Douglas fir (Bu et al., 2012) and wheat straw (Zhao et al., 2012). Omar et al. (2010) conducted MW pyrolysis of EFB

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