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Physicochemical and structural characterisation of oil palm trunks (OPT) hydrochar made *via* wet torrefaction

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ABSTRACT

This study evaluates the effect of wet torrefaction of OPT under autogenous pressures at 3 different relatively low temperatures (i.e. 180, 200, and 220 °C) and extended residence times (i.e. 3, 6, 9, 12, 18, 24, 48, and 72 h) on the hydrochar's physical, chemical, and structural properties. Logarithmic-like increase of HHV profile was observed at the highest temperature of 220 °C, in which a plateau was reached at 24 h. Between temperature and residence time, temperature gave a more significant influence on the characteristics of the produced biochar. The HHV of the biomass sample increases from 16.4 MJ kg^{-1} in raw OPT to the highest HHV of 26.9 MJ kg^{-1} when torrefied at 220 °C for 72 h. Van Krevelen analysis shows dehydration was the primary reaction pathway that occurred during wet torrefaction of OPT at 180 °C for 24 h, 200 °C for 24 h, 220 °C for 6 h, and 220 °C for 12 h. Decarboxylation dominates the reaction when temperature and residence time was increased to 220 °C for 24 h, respectively. Further increasing the residence time to 48 and 72 h at 220 °C promotes demethylation as the dominant reaction. FTIR analysis reveals that most hemicellulose and parts of cellulose decomposed when OPT was subjected to lower temperature and/or residence time (i.e. 180 °C for 24 h, 200 °C for 24 h, 220 °C for 6 h, and 220 °C for 12 h). However, increasing temperature to 220 °C and beyond 24 h resulted in carbon-rich and lignin-dense hydrochar, which was observed in powder XRD results where graphite nitrate peak at 2θ of 7.4° appears. Morphology analysis reveals that most of the hemicellulose and cellulose-rich parenchyma was removed when subjected to wet torrefaction at 220 °C for 24 h. The formation of microspheres from the repolymerisation of 5-HMF was observed in large quantities in OPT hydrochar treated at 220 °C for 72 h. Inorganic elemental analysis shows that wet torrefaction of OPT effectively removes K and Cl from the biomass. The removal of K increased with increased temperature, which may partially resolve the corrosion problems in combustion reactions related to silicate deposition. OPT hydrochar from WT under autogenous condition and relatively low temperature exhibits much more improved fuel properties compared to raw OPT.

1. Introduction

The use of fossil fuels has caused environmental concerns given their high CO_2 emission into the atmosphere that leads to global warming. Factoring in the current rate of fossil fuels consumption due to the ever-growing industrialisation and globalisation, the continuous use of fossil fuel as primary energy production will eventually lead to the exhaustion of fossil fuels, which may lead to price spike in fossil fuels in the upcoming future. An attractive alternative to fossil fuels is biomass. Biomass when used as fuel is considered carbon neutral since its growth uses as much CO_2 as it releases when burned (Lynam et al., 2015). It is also easily obtained and highly abundant, thus making it as one of the desired materials for renewable bio-fuel production. Local agricultural waste can also be managed holistically with biomass as an alternative renewable energy source. As the world's second largest palm oil producer, Malaysia accounts for up to 311 million tonnes of oil palm

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