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Gas-pressurized torrefaction of biomass wastes: Roles of pressure and secondary reactions

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ABSTRACT

A gas-pressurized (GP) torrefaction method, proposed in our resent work, can significantly promote the upgrading and oxygen removal of biomass wastes, compared to the traditional torrefaction (AP). However, the mechanism of the GP torrefaction process is not clear. In present work, semi-closed (SC) torrefaction, GP torrefaction, and AP torrefaction were conducted to reveal the roles of pressure and secondary reactions during GP torrefaction quantitatively. The results showed that the pressure significantly promoted the upgrading of biomass during GP torrefaction at 200 °C. The contribution of pressure on the oxygen removal of GP torrefaction at 200 °C was 63.87%. At relatively high temperature of around 250 °C, the promotions were caused by the synergistic effect of pressure and secondary reactions. The contribution of secondary reactions on the oxygen removal was 53.99%. Thus, the process of the GP torrefaction of biomass wastes was preliminarily understood.

1. Introduction

Nowadays, biomass energy has the largest share of renewable energies in the world (Hu et al., 2020). In the short to medium term, it is also the most promising energy source, in terms of its use as an alternative to fossil fuels to control greenhouse gas (GHG) emissions (Su et al., 2018). However, the raw biomass is unpopular in the industry from the viewpoint of fuel. The drawbacks of biomass energy, compared to fossil fuels, include hygroscopic nature, high moisture content, low energy density, low grindability, etc (Cahyanti et al., 2020; Chen et al., 2017; Zhu et al., 2020). Hence, one of the main challenges in biomass utilization is the development of efficient pretreatment technology to upgrade the biomass and make it comparable with fossil fuel. Torrefaction is a favorable pretreatment technology, which can largely eliminate aforementioned defects of raw biomass feedstock (Tian et al., 2020). It is regarded as a biomass thermal treatment at atmospheric pressure and temperatures within the range of 200 – 300 °C under an inert environment (Kai et al., 2019). By torrefaction, the moisture, oxygen containing functional groups and volatile matter in biomass are reduced. Consequently, the calorific value of the biomass is improved, and these can be further promoted by increasing the torrefaction temperature and time (Cahyanti et al., 2020; Niu et al., 2019; Sukiran et al., 2017). Besides, the torrefaction is also beneficial for the biomass grinding, suppressing the tar formation during the biomass gasification, and so on (Bach et al., 2017; Chen et al., 2013; Couhert et al., 2009; Felfli et al., 2005; Prins et al., 2006a,b; Repellin et al., 2010; Tapasvi et al., 2015; Wannapeera et al., 2011; Xiao et al., 2015; Yan et al., 2009).

Although the torrefied biomass has various advantages, the industrial application of biomass torrefaction is still not so much due to the limited upgrading degree for biomass by traditional torrefaction. For example, the oxygen contents in torrefied biomass by the traditional method still ranges from 28% to 46% (Chen et al., 2015; Chew and Doshi, 2011; Rousset et al., 2011; van der Stelt et al., 2011). Hence, more attention has been paid on the optimization of the traditional torrefaction to improve the upgrading effectivity, recently. For example, long torrefaction time and severe temperature, microwave heating, non-inert atmosphere, catalytic additives and so on are studied widely for the torrefaction (Chen et al., 2012; Couhert et al., 2009; Ho et al., 2018; Huang et al., 2017; Li et al., 2016, 2017; Saadon et al.,

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