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Combustion and gasification characteristics of chars from raw and torrefied biomass

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HIGHLIGHTS

- Chars from torrefied and raw biomass were prepared at low and high heating rates.
- High-heating-rate chars are more reactive than low-heating-rate chars.
- Chars from torrefied biomass are less reactive than chars from raw biomass.
- Torrefaction's impact on reactivity is greatest for high-heating-rate chars.
- Morphology differences were observed for chars from torrefied vs. raw biomass.

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ABSTRACT

Torrefaction is a mild thermal pretreatment (T < 300 °C) that improves biomass milling and storage properties. The impact of torrefaction on the gasification and oxidation reactivity of chars from torrefied and raw biomass was investigated. Thermogravimetric analysis was used to study the differences in O_2 and steam reactivity, between chars prepared from torrefied and raw willow, under both high- and low-heating-rate conditions. High-heating-rate chars were prepared at 900 °C with a residence time of 2 s. Low-heating-rate chars were prepared with a heating rate of 33 °C/min, a maximum temperature of 850 or 1000 °C, and a residence time of 30 min or 1 h, respectively, at the maximum temperature. Pretreatment by torrefaction consistently reduced char reactivity. Torrefaction's impact was greatest for high-heating-rate chars, reducing reactivity by a factor of two to three. The effect of torrefaction on a residence time requirements for char burnout and gasification was estimated.

1. Introduction

Torrefaction is a mild thermal pretreatment that occurs below 300 °C under an inert atmosphere. Under these conditions the initial biomass is converted mainly into a solid product whose properties are intermediate between coal and biomass. As described by Chew and Doshi (2011), the torrefied product has a brown color, decreased H/C and O/C ratios, and an increased energy density. In addition, it is hydrophobic, brittle and, in comparison to raw biomass, more easily fluidizable (Svoboda et al., 2009) and less prone to agglomerate (Chen et al., 2011). These properties give the torrefied product advantages over raw biomass for transportation, storage, milling and feeding. Hence, torrefaction appears as a very promising pretreatment for co-firing with pulverized coal in existing large industrial facilities and gasification in entrained flow reactors.

Biomass combustion or gasification consists of two partially overlapping processes: (1) the release of water and volatiles, i.e. pyrolysis (also known as volatilization or charring), followed by (2) the slower reaction of the solid residue (char) with oxygen or steam, respectively. As the second process is slower than the first, it has an important impact on reactor sizing, control and efficiency (Costa et al., 2003; Di Blasi, 2009; Dupont et al., 2011). Char properties depend strongly on pyrolysis conditions, especially on the heating rate during pyrolysis (Di Blasi, 2009). Although there is no one generally accepted definition of char reactivity, it is possible to determine a global char reactivity from mass loss histories, by defining it as the time derivative of the conversion. This global reactivity is influenced by the char surface area and surface accessibility as well as by intrinsic kinetic parameters.

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