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Physical and chemical characteristics of products from the torrefaction of yellow poplar (*Liriodendron tulipifera*)

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ABSTRACT

We investigated the characteristics of torrefied yellow poplar (*Liriodendron tulipifera*) depending on reaction time (30 min) and temperature (240–280 °C). The thermogravimetric, grindability and calorific value of torrefied biomass were analyzed. As the torrefaction temperature increased, the carbon content of torrefied biomass increased from 49.50% to 54.42%, while the hydrogen and oxygen contents decreased from 6.09% to 5.65% and 28.71% to 26.61%, respectively. The highest calorific value was 1233 kJ/kg when torrefaction was performed at 280 °C for 30 min. An overall increase in energy density and decrease in mass and energy yield was observed with the increase in torrefaction temperature. The analysis of thermal decomposition demonstrated that the hemicelluloses contained in torrefied biomass decreased with increasing torrefaction temperature, whereas cellulose and lignin were only slightly affected. The grindability of torrefied biomass was significantly improved when torrefaction was performed at high temperature. Torrefaction of yellow poplar improved the chemical and physical fuel properties of the biomass.

1. Introduction

The demand for biofuel pellets has increased due to conversion of fossil fuel-based heating systems (Nilsson et al., 2011; Stahl and Berghel, 2011); however, compared to coal, these lignocellulosic pellets have a relatively high moisture content, low energy density, a hydrophilic behavior and are difficult to store (Chen and Kuo, 2011). Furthermore, lignocellulosic biomass pellet do not have consistent calorific values and ash contents because pellet can be produced from various resources.

Torrefaction of lignocellulosic biomass has attracted interest because of its potential to overcome the disadvantages of current biofuel pellets (Chen and Kuo, 2011; Repellin et al., 2010). Torrefaction is a process where raw biomass is heated in an inert or nitrogen atmosphere at a temperature of 200–300 °C. This process produces a hydrophobic material due to the removal of hydroxyl groups during thermal treatment. Therefore, torrefied lignocellulosic biomass is suitable for long distance transportation and long term storage. Additionally, torrefied products have a higher calorific value or energy density, a lower O/C ratio and moisture content, and are easier to grind than untreated biomass. During torrefaction of biomass, most of the volatile compounds are removed from the biomass as vapors, resulting in a higher energy density. Torrefaction temperature is usually within the range of 250–300 °C for lignocellulosic biomass (Prins et al., 2006; Chen et al., 2011; Phanphanich and Mani, 2010). Chen et al. (2011) suggested that biomass torrefied for less than 1 h under light torrefaction (260 °C) was appropriate for producing fuels with desirable energy density. Therefore, the physical and chemical properties of yellow poplar (*Liriodendron tulipifera*) torrefied at 250–300 °C for 30 min were evaluated in the present study.

Yellow poplar has been reported to acclimate well to barren soil or highlands. Its fast growth and high capacity for carbon absorption has led the Korea Forest Service to value this species as a major planting species and it has thus been planted extensively in Korea for the production of woody biomass (Gwak et al., 2009).

2. Methods

2.1. Materials

Yellow poplar chips were provided by the Korea Forest Research Institute. Wood chip were screened to the size of 3–10 and 10–30 mm, using sieves (9.5 and 31.5 mesh) and dried to below 10% moisture content for safe outside storage.

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