Influence of pyrolysis temperature on physicochemical properties of biochar obtained from the fast pyrolysis of pitch pine (*Pinus rigida*)

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Highlights

- Biochar was obtained as byproducts during fast pyrolysis of pitch pine at various temperatures.
- Yield of biochar decreased sharply from 60.7% to 14.4% with pyrolysis temperature.
- Carbons in the biochars were rearranged to highly ordered aromatic form.

Abstract

The aim of this study was to investigate the influence of pyrolysis temperature on the physicochemical properties and structure of biochar. Biochar was produced by fast pyrolysis of pitch pine (*Pinus rigida*) using a fluidized bed reactor at different pyrolysis temperatures (300, 400 and 500 °C). The produced biochars were characterized by elemental analysis, Brunauer–Emmett–Teller (BET) surface area, particle size distributions, field-emission scanning electron microscopy (FE-SEM), Fourier transform infrared (FTIR) spectroscopy, solid-state 13C nuclear magnetic resonance (NMR) and X-ray diffraction (XRD). The yield of biochar decreased sharply from 60.7% to 14.4%, based on the oven-dried biomass weight, when the pyrolysis temperature rose from 300 °C to 500 °C. In addition, biochars were further carbonized with an increase in pyrolysis temperature and the char's remaining carbons were rearranged in stable form. The experimental results suggested that the biochar obtained at 400 and 500 °C was composed of a highly ordered aromatic carbon structure.

1. Introduction

Thermochemical conversion technologies including combustion, pyrolysis and gasification have attracted increased interest since they offer a flexible and simple way to convert biomass into fuels and chemicals (Yanik et al., 2007). Product distributions and compositions depend upon experimental conditions (Bahng et al., 2009; Brewer et al., 2009; Bridgwater et al., 1999), thus thermochemical processes are widely applicable in respect that those technologies can convert bulky and heterogeneous forms of biomass into useful forms tailored to user needs. Fast pyrolysis, a representative thermochemical processing technology, can be used to produce liquid fuel from dry biomass sources with high yield (~70 wt.%) (Bridgwater and Peacocke, 2000; Czernik and Bridgwater, 2004). Although fast pyrolysis has been optimized for biooil production, typically 15–20% of the feedstock mass is converted into solid-state biochar.

Biochar derived from biomass is defined as a carbonaceous residue from pyrolysis, including natural fires under limited oxygen (Brown, 2009). The formation of biochar from biomass is complex and remains unclear. Demirbas (2004) suggested reaction mechanisms for biomass pyrolysis and char formation.

1st step: Biomass → Water + Unreacted residue
2nd step: Unreacted residue → (Volatile + Gases)1 + (Char)1
3rd step: (Char)1 → (Volatile + Gases)2 + (Char)2

According to these mechanisms, biochar is produced through three reaction steps. Primary biochar formed during the second step further decomposes to carbon-rich residual solids by chemical rearrangement of the biochar. Biochar has recently received much attention, even though its structure is still uncertain. Biochar has potential as a soil amendment, natural fertilizer and/or carbon sequestration agent (Brewer et al., 2009).

Biochar can be used as a soil amending agent because it contains most mineral nutrients, is a good absorbent of nutrients and agricultural chemicals and may also sequester carbon (Mullen...