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Hydrothermal conversion of big bluestem for bio-oil production: The effect of ecotype and planting location

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ABSTRACT

Three ecotypes (CKS, EKS, IL) and one cultivar (KAW) of big bluestem (*Andropogon gerardii*) that were planted in three locations (Hays, KS; Manhattan, KS; and Carbondale, IL) were converted to bio-oil via hydrothermal conversion. Significant differences were found in the yield and elemental composition of bio-oils produced from big bluestem of different ecotypes and/or planting locations. Generally, the IL ecotype and the Carbondale, IL and Manhattan, KS planting locations gave higher bio-oil yield, which can be attributed to the higher total cellulose and hemicellulose content and/or the higher carbon but lower oxygen contents in these feedstocks. Bio-oil from the IL ecotype also had the highest carbon and lowest oxygen contents, which were not affected by the planting location. Bio-oils from big bluestem had yield, elemental composition, and chemical compounds similar to bio-oils from switchgrass and corncobs, although mass percentages of some of the compounds were slightly different.

1. Introduction

Andropogon gerardii Vitman, commonly known as big bluestem, is a dominant grass in the tallgrass prairies of North America (Weaver and Fitzpatrick, 1932; Knapp et al., 1998). Big bluestem is widely distributed on loamy soils in Midwest United States grasslands and comprises up to 80% of prairie biomass (Knapp et al., 1998). Although photosynthesis in C_4 grasses is highly sensitive to water stress (Ghannoum, 2009), big bluestem is capable of maintaining high photosynthetic rates during periods of water shortage (Knapp, 1985) owning to its efficient water usage and resource allocation (Johnson and Matchett, 2001). Conversion of native perennial grasses such as big bluestem to biofuels offers major economic, environmental, and strategic benefits. Compared with switchgrass, the first-generation dedicated bioenergy species, big bluestem was found to produce three times more biomass (Epstein et al., 1998) with less (or no) irrigation or nitrogen fertilizers needed. Moreover, big bluestem was found to have higher cellulose and lignin contents and greater fermentability than switchgrass (Jung and Vogel, 1992), which are important qualities for biofuel conversion.

McMillan conducted early studies investigating the ecotype effects of several grasses, including big bluestem. Six ecotypes of big bluestem were collected across the United States from north to south and were planted in Texas (McMillan, 1965a) or in growth chambers with temperature and light-period controls (McMillan, 1965b). Results indicated that vegetation of big bluestem was affected by its ecotype and growth climate. Jefferson and co-workers (2002, 2004) also found that planting location had significant effects on big bluestem biomass production and its cellulose and hemicellulose contents in the Canadian prairie provinces. They found that big bluestem could not be well cultivated at sites above 51°N latitude in western Canada, and its cellulose and hemicellulose contents were lower than in lower latitude areas.

Cellulose, hemicellulose, and lignin are the three major compounds of lignocellulosic biomass. Higher cellulose content in biomass generally favors higher ethanol yield in biochemical conversion. Thermochemical conversion is another promising technology to convert lignocellulosic biomass such as big bluestem into bio-fuels. As one of the thermochemical conversion processes, hydrothermal conversion (HTC) has been extensively investigated for the production of bio-oil, which can be used as a fuel for stationary diesel engines, burners, boilers or turbines (Czernik and Bridgwater, 2004), or can be upgraded or further converted to transportation fuels (e.g., gasoline and diesel) and products such as polymers, aromatics, lubricants, and asphalt (Peterson et al., 2008). HTC is a chemical reforming process in which hot compressed water (or other solvents) is used as reaction medium with which biomass is depolymerized and reformed to gases, water-soluble matters, bio-oil, and char in an oxygen-absent enclosure.

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