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Short Communication

Invasive plants as feedstock for biochar and bioenergy production

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HIGHLIGHTS

- Invasive plants can be used as pyrolysis feedstock for valued added products.
- AP and BP showed similar biochar yields to traditional pyrolysis feedstock.
- Biochar production decreases with increasing of pyrolysis temperature.
- Minimum residence time is linearly correlated with feedstock weight.

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ABSTRACT

In this work, the potential of invasive plant species as feedstock for value-added products (biochar and bioenergy) through pyrolysis was investigated. The product yield rates of two major invasive species in the US, Brazilian Pepper (BP) and Air Potato (AP), were compared to that of two traditional feedstock materials, water oak and energy cane. Three pyrolysis temperatures (300, 450, and 600 °C) and four feedstock masses (10, 15, 20, and 25 g) were tested for a total of 12 experimental conditions. AP had high biochar and low oil yields, while BP had a high oil yield. At lower temperatures, the minimum feedstock residence time for biochar and bioenergy production increased at a faster rate as feedstock weight increased than it did at higher temperatures. A simple mathematical model was successfully developed to describe the relationship between feedstock weight and the minimum residence time.

1. Introduction

The rapid spreading of invasive plants poses an increasing threat to natural ecosystems throughout the United States and other countries in the world (de Lange and van Wilgen, 2010; Eviner et al., 2012; Weidenhamer and Callaway, 2010). In addition, invasive plants may also present risk to public health and economies. In the State of Florida alone, the impact of invasive plants on ecosystems and economy costs millions of dollars each year. As a result, several management strategies have been developed. Among them, mechanical (e.g., pulling and digging) and chemical (e.g., herbicides) control methods are most commonly used (Getsinger, 2010; Love and Anderson, 2009; Simmons et al., 2007). Although these methods are effective, they often require huge capital and human resources with little or no direct return. Furthermore, the application of herbicides or other chemical control agents may impose unintended risks to native species and public health. Therefore, there is a critical need to develop innovative and cost-effective strategies to control invasive plants.

Recent developments in biochar technology make it possible to envision a new strategy to manage invasive plants by converting them into value-added products, such as biochar and bioenergy. Biochar is a black carbon-rich product with a great potential for long-term carbon sequestration due to its high resistance to decomposition (Lehmann et al., 2011; Zimmerman et al., 2011). Biochar technology has received increasing attention recently because it provides an immediate solution to global warming caused by emissions of CO_2 and other greenhouse gasses (Matovic, 2011; Spokas and Reicosky, 2009). In other words, biochar withdraws net carbon dioxide from the atmosphere and stores it as stable carbon in soil 'sinks'. When biochar is applied in soils, it may also function as an amendment to sustain fertility on poor soils and to support plant growth, particularly in the tropics (Glaser et al., 2001; Lehmann et al., 2011). Moreover, biochar amendment may reduce environmental pollution by retaining soil nutrients and limiting the amount of applied fertilizers that is leached to water resources (Yao et al., 2012; Zhang et al., 2012). In the literature, biochar has been produced from various biomass feedstocks; however, no/little research effort has been made to evaluate the production of biochar from invasive plants.

The overarching objective of this work was to develop an innovative strategy to produce value-added biochar as well as bioener-

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gy from invasive plants. Two invasive species, Brazilian Pepper (BP) and Air Potato (AP), were used. BP is an aggressive, evergreen shrub-like tree, which has invaded many habitats in California, Florida, Hawaii, Louisiana, and Texas by forming large dense forests. AP is a vine that was imported to the US from Africa as a horticultural and ornamental plant. Both BP and AP are among the most invasive plant species in the southeastern United States and destroy local ecosystems by preventing sunlight from reaching native plants.

2. Methods

2.1. Biomass

The invasive plants, BP and AP, and two standard biomass feedstocks, WO and EC, were obtained locally from Gainesville, Florida and stored in airtight bags until ready for use. The original biomass samples were cut into smaller strips with a length between 5 cm and 10 cm. The strips were further ground in a knife mill (Model No. 4, Arthur H. Thomas Company, Philadelphia, PA) to achieve even smaller particles. The final size of the sample was between 0.5 mm and 1 mm after sieving. Samples were dried in an oven at 100 °C for 12 h to remove moisture before pyrolysis.

2.2. Biochar production

A bench-scale pyrolyzer was used to convert the feedstocks into biochar. 15 g of dried samples were fed into a custom-made, stainless steel, mini tubular reactor (6 cm diameter cylinder 28 cm long) designed to fit inside a bench-top furnace (Barnstead 1500 M). The tubular reactor was first purged with nitrogen gas (10 psi) and an oxygen sensor attached to the reactor ensured that the oxygen content in the reactor was less than 0.5% before it was inserted into the furnace. The reactor was purged again with N_2 along with the furnace and sealed for pyrolysis. The controller of the bench-top furnace was programmed to drive the furnace temperature to the desired temperature (i.e., 300, 450, and 600 °C) at a rate of 20 °C/min and held at the peak temperature until no more gas or oil was generated. Small vials (SC480-W-SC475, Environmental Express, Charleston, SC) were used to collect biofuel flowing from the pipe. The biochar in the reactor was naturally cooled down to room temperature by turning off the furnace. The biochar and oil obtained were weighed in order to determine yield in grams. The gas yield was calculated by subtracting the total weight of the oil and char yields from the mass of the feedstock. To determine the relationship between residence time and feedstock amount, different weights of BP (10 g, 15 g, 20 g, and 25 g) were fed into the reactor and the reaction time was recorded for running temperatures of 300 °C, 450 °C, and 600 °C.

3. Results and discussion

3.1. Biochar and bioenergy production

Fig. 1(a) shows the yields of biochars from different feedstock materials at the three pyrolysis temperatures (i.e., 300, 450, and 600 °C). As shown in the figure, all the biomass samples were effectively converted into biochar through slow pyrolysis with production rate ranging from 25.1% (WO at 600 °C) to 52.8% (BP at 300 °C) of the initial dry weight. Compared to the traditional biomass feedstock material, both BP and AP had similar yields of biochars at the same pyrolysis temperatures. This result indicates that the two invasive plants can be used as feedstock materials to produce value-added biochars. The biochar production rate of each biochar decreased with increasing temperature,

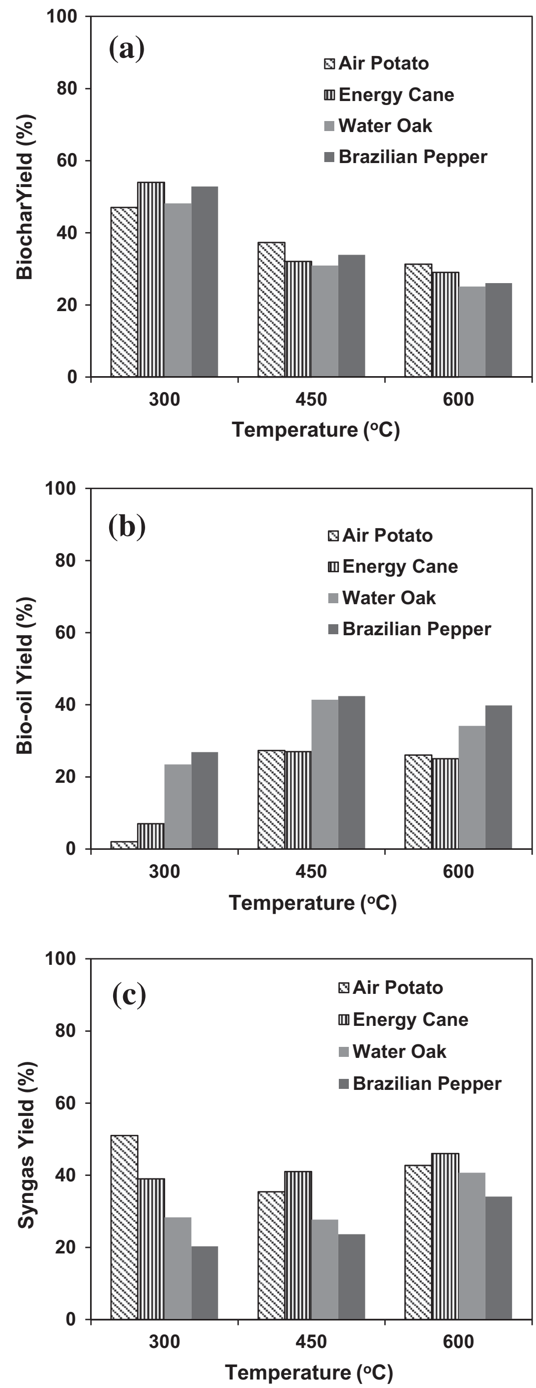

Fig. 1. Comparisons of the yield of (a) biochar, (b) bio-oil, and (c) syngas from different biomass materials at three pyrolysis temperatures at the minimum residence time.

which is consistent with findings of previous studies (Hossain et al., 2011). When the pyrolysis temperature increased from 300 to 600 °C, the biochar production rate was reduced by almost 50% for almost all of the feedstock materials. In addition to lower biochar production rates, previous studies have also indicated that higher pyrolysis temperatures may result in greater surface areas, elevated pHs, higher ash contents, lower cation exchange capacities, minimal total surface charges, concentrated mineral contents, and higher percentages of carbon but much lower hydrogen and oxygen contents (Gaskin et al., 2008; Kloss et al., 2012; Novak et al., 2009).