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Fast pyrolysis of microalgae remnants in a fluidized bed reactor for bio-oil and biochar production

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HIGHLIGHTS

▶ Lipid-extracted microalgae remnants were pyrolyzed in a fluidized bed reactor.
▶ Bio-oil yield of 53% was achieved while biochar and gas yield were 31% and 10%.
▶ Ninety-four percent of the energy content of algal biomass was recovered in bio-oil and biochar.

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ABSTRACT

In this study, pyrolysis of microalgal remnants was investigated for recovery of energy and nutrients. *Chlorella vulgaris* biomass was first solvent-extracted for lipid recovery then the remnants were used as the feedstock for fast pyrolysis experiments using a fluidized bed reactor at 500 °C. Yields of bio-oil, biochar, and gas were 53, 31, and 10 wt.%, respectively. Bio-oil from *C. vulgaris* remnants was a complex mixture of aromatics and straight-chain hydrocarbons, amides, amines, carboxylic acids, phenols, and other compounds with molecular weights ranging from 70 to 1200 Da. Structure and surface topography of the biochar were analyzed. The high inorganic content (potassium, phosphorous, and nitrogen) of the biochar suggests it may be suitable to provide nutrients for crop production. The bio-oil and biochar represented 57% and 36% of the energy content of the microalgae remnant feedstock, respectively.

1. Introduction

There is growing interest in utilizing microalgae as a feedstock for next-generation biofuels production due to its high biomass yield, its high lipid content, and the prospects of avoiding competition with arable land and recovering nutrients for use in conventional agriculture (DOE, 2010; Wijffels and Barbosa, 2010; Williams and Laurens, 2010). Based on the photosynthetic efficiency and growth potential for algae, oil yields per hectare for certain algal strains are projected to be at least 60 times higher than those for soybean, which currently accounts for 90% of biodiesel production feedstock in the US (DOE, 2010). Many algal biofuel studies have focused on producing biodiesel (fatty acid methyl esters) from microalgae species with high lipid contents (Hu et al., 2008). Such a production scheme will result in large quantities of lipid-extracted algal remnants. How to best use these algal remnants is one of the greatest challenges for algal biorefineries (DOE, 2010). The remnants, which contain protein, carbohydrates, and a small amounts of lipids, have potential for use as an animal feed. At the scale of replacing petroleum with microalgae as the feedstock for the US gasoline supply, however, 750 million tons of algal remnants would be produced annually – 50 times the amount of feed supplement required by the 100 million cattle in the US. Furthermore, algae are effective at capturing and concentrating heavy metals, which could potentially make its use as an animal feed problematic (Becker, 2006).

Pyrolysis, the thermal conversion of materials in the absence of oxygen, has potential for converting algal remnants into bio-oil for upgrading to fuels and other value-added products; fast pyrolysis has already been developed for converting lignocellulosic biomass into advanced biofuels (Mohan et al., 2006). Pyrolysis yields three products: gas, solid, and liquid. Pyrolysis gas is a flammable mixture of carbon monoxide, hydrogen, carbon dioxide, and light hydrocarbons suitable for generating process heat. The solid biochar product is primarily reduced aromatic carbon and contains

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