Bioresource Technology 130 (2013) 777–782

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Catalytic pyrolysis of microalgae and their three major components: Carbohydrates, proteins, and lipids

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HIGHLIGHTS

- Cellulose, egg whites, and canola oil were pyrolyzed as the model compounds.
- Several pyrolysis pathways of algal biomass were postulated.
- Catalytic pyrolysis with HZSM-5 significantly increased the aromatic yield.
- Proteins can hardly be converted to aromatics with HZSM-5.

ARTICLE INFO

Article history:
Received 5 November 2012
Received in revised form 13 December 2012
Accepted 14 December 2012
Available online 22 December 2012

Keywords:
Pyrolysis
Microalgae
Bio-oil
Model compounds

ABSTRACT

To better understand the pyrolysis of microalgae, the different roles of three major components (carbohydrates, proteins, and lipids) were investigated on a pyroprobe. Cellulose, egg whites, and canola oil were employed as the model compounds of the three components, respectively. Non-catalytic pyrolysis was used to identify and quantify some major products and several reaction pathways were proposed for the pyrolysis of each model compound. Catalytic pyrolysis was then carried out with HZSM-5 for the production of aromatic hydrocarbons at different temperatures and catalyst to feed ratios. The aromatic yields of all feedstocks were significantly improved when the catalyst to biomass ratio increased from 1:1 to 5:1. Egg whites had the lowest aromatic yield among the model compounds under all reaction conditions, which suggests that proteins can hardly be converted to aromatics with HZSM-5. Lipids, although only accounted for 12.33% of *Chlorella*, contributed about 40% of aromatic production from algal biomass.

1. Introduction

Microalgae have received growing interest recently because of their high productivity, high oil content and the ability to grow in a wide range of climates and lands (Schenk et al., 2008). However, conversion of microalgae to biofuels is still a challenge. Traditional algal biodiesel is produced via costly extraction of oil by organic solvents followed by transesterification reaction. Since microalgae contain a significant amount of free fatty acids, acid catalysts need to be used firstly to convert free fatty acids into fatty acids esters, which require much longer conversion time than basic catalysts (Ehimen et al., 2010; Paik et al., 2009). Another issue with algal biodiesel is that only oil portion can be utilized and the rest is considered as waste in terms of fuel use (Wang et al., 2013).

Recently, another conversion route, pyrolysis, has received growing attention in conversion of whole microalgae. During pyrolysis, organic materials are thermally decomposed in the absence of oxygen and the condensed liquid is referred as bio-oil (Mohan et al., 2006). Although pyrolysis has been studied extensively on lignocellulosic biomass, few studies have been carried out using microalgae as the feedstock. The reported results (Du et al., 2011, 2012; Li et al., 2012; Maddi et al., 2011; Thangalazhy-Gopakumar et al., 2012) showed that algal bio-oil has better qualities in many aspects than that produced from lignocellulosic biomass. For example, algal bio-oil has higher heating value, lower oxygen content, and desirable pH. However, algal bio-oil contains many oxygenates and nitrogenates (Jena and Das, 2011; Maddi et al., 2011; Pan et al., 2010), which make it difficult for direct use as drop-in fuels. Thus, both homogeneous (Babich et al., 2011) and heterogeneous catalysts (Thangalazhy-Gopakumar et al., 2012) were applied to pyrolysis of microalgae, aiming to improve the quality of algal bio-oil. It was found that zeolite HZSM-5 increased the carbon yield of aromatic hydrocarbons from 0.9 to 25.8% for pyrolysis of *Chlorella vulgaris* (Thangalazhy-Gopakumar et al., 2012).

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http://dx.doi.org/10.1016/j.biortech.2012.12.115