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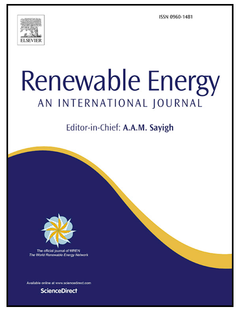

Thermal fractionation and catalytic upgrading of lignocellulosic biomass to biofuels: Process synthesis and analysis

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Thermal fractionation and catalytic upgrading of lignocellulosic biomass to biofuels: Process synthesis and analysis

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Abstract

Multi-stage thermal biomass decomposition coupled with catalytic upgrading has a number of advantages over conventional single-stage pyrolysis with hydrotreating. However, significant gaps still exist in our understanding of the design of such processes. In this paper, we synthesize alternative catalytic upgrading strategies through integration of different chemistries. Using experimental data, we develop a process model for all strategies and conduct heat integration to minimize utility requirements. Then, using a wide range of technoeconomic analyses, we identify (1) the relationship between process complexity and the resulting fuel-range carbon yields and economic feasibility, (2) the economic advantage of integrating different thermal decomposition fractions, and (3) the key cost drivers of the integrated processes.

Keywords: Biofuel, Pyrolysis, Process design, Catalysis, Renewable energy, Technoeconomic analysis

1. Introduction

Biomass can be upgraded into liquid fuels or chemicals using four main platforms (Huber et al., 2006): (1) gasification followed by catalytic conversion (Balat et al., 2009; Gao et al., 2008; Steele et al., 2013; Xu et al., 2010), (2) hydrolysis followed by fermentation or dehydration (Han et al., 2015; Humbird et al., 2011; Luterbacher et al., 2014; Serrano-Ruiz et al., 2011; Won et al., 2017), (3) thermochemical liquefaction followed by catalytic conversion (Elliott et al., 1991; Dutta et al., 2015; Mohan et al., 2006; Yaman, 2004; Wright et al., 2010), and (4) catalytic decomposition and conversion (Alonso et al., 2017; Gürbüz et al., 2013; Han et al., 2014; Xing et al., 2010). Among these alternatives, thermochemical processing has recently received increased attention, due to its high efficiency, and great versatility in terms of feedstocks and final products (Bridgwater, 2012; Chew et al., 2011). Early studies of thermochemical conversion focused mainly on fast pyrolysis, which involves rapid heating of biomass in the absence of air at approximately 500 °C (Bridgwater et al., 1999; Dutta et al., 2015; Wright et al., 2010). While fast pyrolysis is the simplest method of obtaining liquid streams from solid biomass, the resulting bio-oil (also referred as pyrolysis-oil) contains a large number of oxygenated compounds (e.g., organic acids, aldehydes, ketones, etc.), which are chemically unstable and difficult to upgrade catalytically (Mullen et al., 2010; Venderbosch et al., 2010). Multi-stage thermal decomposition of biomass provides a promising alternative for overcoming these issues (Pham et al., 2014a)