

Biomass to Fuels: Impact of Reaction Medium and Heating Rate

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Abstract

We have recently reported on the impact of CO₂ on biomass gasification and its ability to more effectively gasify biomass than steam. Continuing this investigation has led to understanding the impact of heating rates and different reaction environments. This article presents the results from the gasification of various biomass feedstocks. Heating rates were varied from 1 to 100°C min⁻¹ to ballistic rates (~500°C min⁻¹). Gasification media investigated include H₂O/N₂, CO₂, CO₂/N₂/H₂O, and O₂/N₂. Global activation energies for pyrolysis were found to be significantly higher than for gasification, whereas those for the grasses were significantly lower than the woods, possibly indicating a catalytic effect during pyrolysis of the high mineral content herbaceous feedstocks. CO₂ pyrolysis (110–450°C) activation energy values for lignin, cellulose, and biomass were 22–49, 202–230, and 28–72 kJ mol⁻¹, respectively, and CO₂ gasification (500–700°C) values for lignin and biomass were 12–38 and 9–57 kJ mol⁻¹, although cellulose did not exhibit significant mass loss in the gasification interval 500–700°C. Using a least squares fit on the rate of mass loss fraction, the global decomposition reaction during pyrolysis for lignin in either medium was found to be third order, whereas that for cellulose was first order and for the various biomass samples either first or second order. The most significant difference in biomass processing in CO₂, when compared with steam gasification, occurred above 750°C where nearly all of the biomass was converted to volatiles with less than 2% ash remaining after CO₂ gasification. Only when pure CO₂ was used as the gasification medium under a slow heating rate did complete processing of the components to volatile products occur. Gas chromatography analysis has shown the effect of CO₂ on product distribution. Data are presented focusing on the relation between gasification medium, feedstock selection, and major chemical species evolution.

Key words: sustainable systems engineering; sustainability; energy use and resources; CO₂ emissions; global-scale and regional-scale environmental impacts; thermal treatment; waste minimization

Introduction

THE REALIZATION OF A sustainable global economy ultimately rests on the development of an adequate supply of environmentally and economically sustainable alternate energy sources. One of the most promising renewable resources that has the potential for meeting a significant portion of the demand for energy and transportation fuels is biomass. Through gasification, a wide variety of volatile products can be created. A low NO_x, SO_x, and particulate syngas can be produced. This can serve as a fuel or the feedstock can be used to produce H₂ through feeding the CO into a water gas shift (WGS) reactor. Alternatively, if CH₄ production is the desired

outcome, CH₄ can be collected by operating the process at the optimum methanation temperatures for the particular biomass feedstock. If a hydrocarbon feedstock is the ultimate goal, then the process can be controlled thermally and/or catalytically and hydrocarbon fuels (such as gasoline) can be created by a Fischer Tropsch synthesis. One of the most significant attributes of biomass, other than its carbon neutral status, which strategically places it in a position to provide the next generation of chemical feedstocks (particularly for transportation fuels and fuel additives), is its versatility due to a dual polysaccharide (cellulose/hemicellulose) and aromatic (lignin) structure. By suitable control of the gasification process, which includes the temperature program, the gasification medium, and the type and pretreatment of the feedstock, a wide choice of hydrocarbons (both aromatic and aliphatic, oxygenated, and deoxygenated) is possible, which can replace current petroleum-derived chemicals. An important consideration for the feasibility and economic viability of any new

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