Hydrothemal Carbonization: A Renewable Alternative to Fossil Fuels and Respective Evaluation

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Abstract

Humanity is faced with an imminent energy crisis. The exponential growth of the human population and the consequential increase of the required energy on a global scale, the dramatic climate change and the exhaustibility of natural resources combined, force us to strive towards a sustainable future. The majority of energy is being produced by fossil fuels, carriers of high density of primary energy. Their reserves, however, are finite and the rate at which they are physically replenished is extremely slow. The use of biomass as an energy source, despite its current status, is an increasingly attractive option. Biomass is abundant and generally available at a renewable basis. Biomass feedstock includes a wide variety of organic materials that ranges from specifically cultivated crops and harvested wood products to agricultural and industrial waste. It is the only renewable energy resource that can be converted into any fuel form. In addition, biomass does not contribute to the increase of CO2 in the atmosphere. The use of biomass as a fuel, however, faces a series of noteworthy challenges. Despite its abundance, it is characterized by low energy density, a fact tantamount to high cost of transportation and storage. High moisture content, hydrophylic behaviour, heterogeneous nature and poor grindability further increase the cost of biomass applications. Therefore, pretreatment processes need to take place in order to improve the physicochemical properties of the biomass fuel. Hydrothermal carbonization (HTC) is a thermochemical pre-treatment process that improves the characteristics of the organic feedstock in use. HTC, also known as wet pyrolysis, emulates the natural process of coalification. Biomass in the presence of water is heated in a closed environment. The process takes place at subcritical water conditions (below 374 °C and 22 MPa). HTC, apart from liquid and gaseous by-products, results in the production of a solid material rich in carbon. The percentage and composition of the end products are directly tied to the process parameters, with reaction temperature, residence time and water-to-biomass ratio being the most significant. With a further increase of temperature, the processes of hydrothermal liquefaction (above 250 °C) and hydrothermal gasification (supercritical water conditions) take place, both of which are beyond the scope of the present paper. The purpose of this paper is to indicate why hydrothermal carbonization is a reasonable alternative among the existing body of available valorization processes and to evaluate its potential to produce fuels or valuable chemicals. At this point the exact reaction mechanism is under investigation and partially understood. In addition, the process parameters (temperature, residence time and water-to-biomass ratio) and the composition of the organic feedstock play significant roles in the characteristics of the formed products. That is the reason why the process has been investigated only for specific types of biomass under specific process conditions. The

hydrothermal carbonization of various types of organic feedstock was simulated using the proposed reaction kinetics schemes that were experimentally developed. The resulting systems of partial differential equations were solved using the Chemical Reaction Engineering Module of COMSOL Multiphysics®.