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Review Article

Utilization of CO_2 in thermochemical conversion of biomass for enhanced product properties: A review

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ABSTRACT

CO_2 is the primary greenhouse gas emitted through human activities. CO_2 emissions from burning fossil fuels increased by approximately 2.7 percent in 2018, after global emissions of 35.8 Gt in 2017. Thus, finding energy and cost-effective methods to use the CO_2 generated from industries for productive purposes is crucial, abating CO_2 emissions while producing economic benefits. This paper aims to comprehensively review the effects of CO_2 on syngas, biochar and bio-oil from gasification and pyrolysis processes. It was found that the utilization of CO_2 during gasification and pyrolysis provides both control over syngas H_2/CO ratio and biochar with enhanced properties for high value applications. Furthermore, it was determined that co-gasification under CO_2 atmosphere can enhance synergistic effects. Results also showed that the presence of CO_2 can increase the hydrocarbon concentration of bio-oil due to the different reactions that can occur between biomass and CO_2 compared to biomass and N_2. The use of CO_2 as a feedstock also reduces the net CO_2 emissions and therefore provides environmental benefits. However, the utilization of CO_2 during biomass gasification and pyrolysis currently has some limitations, including the endothermic nature of gasification reactions, resulting in large energy and compressed CO_2 inputs, which can be expensive. It is recommended that comprehensive studies to address the current limitations of the utilization of CO_2 in biomass gasification and pyrolysis processes be conducted. Promoting the use of CO_2 is integral to global CO_2 emission reduction, aiding in efforts to achieve CO_2 emission regulations outlined by the Paris Agreement (PA).

1. Introduction

Gasification is an attractive thermochemical process which uses gasifying agents to convert carbon-based feedstock into a combustible product gas [1–4]. The product gas or syngas, mostly contains H_2 and CO that can be used for fuel or power generation. The char produced is a mixture of unconverted organic fraction, largely containing carbon and ash [5]. Compared to incineration and combustion of solid fuel, syngas produced from gasification contains less solid waste and emits fewer harmful gases into the environment. Advanced gasification technology with carbon capture and sequestration (CCS) can permanently store up to 90 % of the CO_2 released from facilities using fossil fuels to produce power and H_2 [3,6,7]. Successful demonstration and implementation of CCS could nearly eliminate coal-related GHG emissions and pollution, improving the environment, health and economy. Pyrolysis is the thermal degradation of biomass in the absence of an oxidizing medium that results in the production of char, oil and gas [8–11]. One significant benefit of pyrolysis is that it can be conducted at lower temperatures (normally 400 − 700 °C) than those required in gasification (> 700 °C) and combustion (> 900 °C) processes [9,12–14]. The presence of metallic compounds in biomass can further reduce the decomposition temperature during the pyrolysis process. Gasification and pyrolysis have therefore been considered sustainable routes to convert carbon-based feedstock into energy, chemicals and transport fuels.

Global warming has predated the effects of man-made greenhouse gases (GHGs), where naturally occurring GHGs were major contributors. However, there is currently an excessive volume of GHGs in

Abbreviations: GHG, Green House Gas; CCUS, Carbon Capture Utilization and Storage; CCS, Carbon Capture and Sequestration; NETs, Negative Emissions Technologies; MSW, Municipal Solid Waste; LHV, Lower Heating Value; HHV, Higher Heating Value; CGE, Cold Gas Efficiency; TGA, Thermogravimetric Analysis; WGS, Water Gas Shift; Bio-DME, Biomass Derived Dimethyl Ether; PM, Particulate Matter; FT, Fischer-Tropsch; TPO, Temperature Programmed Oxidation; RPM, Random Pore Model

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