



論文内容の要旨

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題目

A Comparative Study of Solid Fuels from Lignocellulosic and Non-Lignocellulosic Biomass via Hydrothermal Carbonization

(水熱炭化によるリグノセルロース系および非リグノセルロース系バイオマスからの固体燃料生産)

Hydrothermal carbonization (HTC) is a promising technology, known for converting wide moisture-ranged biomasses without pre-drying. Needless to say, the energy crops as feedstocks vary in sources and constituents, as grouped into 1) 2nd generation, e.g., fibrous agricultural residues, typically consisting of holocellulose and lignin (lignocellulose), and 2) 3rd generation, e.g., algae, often containing protein and lipid (non-lignocellulose). To fill the gap in biomass selection, our study investigated hydrochars from sorghum bagasse (SB) and microalgae (MA) on HTC at 150°C–250°C for 0.5–3.5 h.

(1) Significance of HTC

The RSM–CCD estimated that temperature and time can significantly control the solid recovery (MY) (p -values = 0.00) and gross heat release of hydrochars (HHV) (p -values = 0.00–0.03) at least in a linear relationship, regardless of the biomass types. The optimum condition of maximizing HHV is achieved at 27.54 (SB) and 35.83 MJ kg⁻¹ (MA), respectively, by raising the temperatures to 250°C and times to 3.5 and 3.25 h.

(2) Fuel properties

Dehydration and decarboxylation predominated HTC. Fixed carbon (FC) developed more in the SB hydrochars, in contrast to the MA, forming volatile hydrocarbon (VM). The tendency led to the higher HHV of MA hydrochars at 26.7–36.2 MJ kg⁻¹ than SB at 19.7–28.0 MJ kg⁻¹. However, SB hydrochars are assumed to combust more stably and ignite more decently as the fuel ratios (FR) approached 0.9–1.5. The original energy (EY) of SB also retained 1.8 times more than MA after HTC, rendering its conversion more techno-commercially feasible. Conflation of these fuel properties recommends SB hydrochar (severity factor / SF = 6.63) as steam coal, while MA hydrochar can broadly serve as steam (SF = 4.08–5.90) and coking coals (SF = 6.63), although MA cannot be developed more due to emulsification.

(3) Chemical structures

Hydrolyzed sugars of SB (d-allose) underwent dehydration to form furanics (methyl furan) and condense into aromatics (phenol), as supported by C–O reduction and C=C_{ar} formation. For MA, hydrolyzed fatty acids (hexadecanoic acid) were transformed and adsorbed as aliphatics (hexene) and fatty amides (hexadecanamide) via decarboxylation and amidation as C–H_{al} increased drastically. Moreover, both partial stability decreased as their crystallinity index decreased (CI = 45.5%–24.3% (SB), 35.8%–18.0% (MA)).

(4) Combustion performance and fire-safety storage

As a preliminary, the methods of thermogravimetric analysis and Frank-Kamenetskii theory were successfully applied. Using SB, the combustion occurred at 131°C–475°C, with flame igniting at 215°C and ember burning out at 433°C. The reactivity of ignition and combustion accelerated by 159 and 53 times as the heating rate increased. The activation energy to initiate was 132.91 kJ mol⁻¹. The fire-safe storage is advised below 83°C and 84°C for cylindrical and rectangular box silos with diameter and height of 15 and 10 m to prevent spontaneous ignition.

The unified reactions of three different activation energies might reject the reaction model assumption for pre-exponential determination. Future work on the combustion kinetic triplets can be attempted by applying the model-fitting method to biomass and hydrochars.