学位論文内容の要旨

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学位論文題名

Production of sustainable solid biofuel from waste and lignocellulosic biomass by hydrothermal carbonization

（水熱炭化による廃棄物とリグノセルロース系バイオマスからの持続可能な固体バイオ燃料の生産）

Biomass as an energy source has high potential to replace the fossil fuel due to its renewability and carbon neutral nature. However, biomass is faced with some problems such low energy density and high ash content. Hence, to increase the energy density of biomass, it needs to be pre-treated. One of effective techniques for the pre-treatment of biomass is the hydrothermal carbonization (HTC). The pre-treatment of biomass in HTC process uses hot compressed water at a moderate temperature range of 180 to 280 °C in an autoclave reactor. The solid biofuel produced from HTC is referred to as hydrochar and has energy density close to the coal. However, the requirement to submerge biomass in water to decompose it to form hydrochar in the HTC process usually results in large volume of the post-process liquid phase. The effective way on how to handle the large volume of the post-process water has remained a subject of discussion and a challenge to the full commercialization of HTC in an industrial scale.

Therefore, this study considered increasing biomass-to-water ratio (B/W) as a feasible and cost-effective way to address the post-process wastewater handling from HTC using dairy manure (DM) as a feedstock. Subsequently, due to the high ash content of hydrochar from the DM, a co-hydrothermal carbonization (co-HTC) of the DM and the Japanese larch (JL) was conducted to improve the fuel properties of the produced hydrochar.

1. **Improvement of the fuel properties of dairy manure by increasing the biomass-to-water ratio in hydrothermal carbonization**

To address the post-process water issue, the feasibility of vapor-based HTC (V-

HTC), which minimizes the water required was investigated. Dairy manure (DM) was hydrothermally treated at temperatures of 200, 230, 255 and 270 °C and biomass-to-water ratios (B/W) of 0.1, 0.18, 0.25, 0.43, 0.67 and 1.0 representing L-HTC to V-HTC conditions for 20 minutes. The results showed that the calorific values of the hydrochars increased with increasing temperature and B/W ratio, and the energy density increased by 46%. The proximate and ultimate analyses revealed that the degree of coalification, such as the increase in carbon content and decrease in oxygen and volatile matter, progressed more under V-HTC than L-HTC conditions, likely due to higher acidity. This study showed a potential approach for upgrading a semi-solid-state biomass by V-HTC.

2. **Upgrading the fuel properties of hydrochar by co-hydrothermal carbonization of dairy manure and Japanese larch (*Larix kaempferi*): product characterization, thermal behaviour, kinetics, and thermodynamic properties**

   To further enhance the fuel properties of hydrochar, a co-hydrothermal carbonization (co-HTC) of the dairy manure (DM) and wood shavings from the Japanese larch (*Larix kaempferi*) was investigated. The Japanese larch (JL) was mixed with the DM at 25, 50 and 75 wt.% ratios. Co-HTC was conducted at 260 °C for 20 minutes. Results showed that the solid biofuel properties of the hydrochar improved as the ratio of JL was increased. The produced hydrochars were in the region of lignite and closed to the region of the coal with an increase in the higher heating value (HHV) to 25.1±0.02 MJ/kg. Increased fixed carbon (FC), carbon contents and lowered H/C and O/C ratios were observed at increasing mass ratio of the JL. Hydrochar with ash content of 13.0±0.6% was obtained at 50 wt.% JL. Therefore, hydrochar production by co-HTC of DM and JL was effective and a promising solid biofuel source.

Conclusively, this study found that hydrochar of improved energy properties can be produced to a B/W ratio of 1.0 with no post-process wastewater handling challenges while 50 wt.% JL was found to be an adequate mass ratio to produce hydrochar with improved fuel properties by co-HTC.