学位論文内容の要旨

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学位論文題名

Development of sustainable bioenergy system by integrating hydrothermal carbonization and anaerobic digestion processes

（水熱炭化と嫌気性消化プロセスの統合による持続可能なバイオエネルギーシステムの開発）

The application of lignocellulose biomass as a sustainable resource has gained traction to achieve a reduction in greenhouse gas emissions. Valorization via hydrothermal carbonization (HTC) of lignocellulosic biomass is necessary to convert high moisture biomass to solid fuel with a reduced inorganic content and to improve it biodegradability through hydrolysis of the recalcitrant in lignocellulose biomass that would enhance the production of biogas in anaerobic digestion process. Utilization of anaerobic digestion (AD) process for energy demand and supply regulation are still rare at the industrial scale, probably because they are unstable under some circumstances, such as variation of process conditions. This drawback can be overcome by developing an adaptive identifier system that will enhance the stable performance of the online biogas production. Thus, the objectives of this studies are (1) Investigating the effect of processing parameters on the products of hydrothermal carbonization of corn stover. (2) Development of an adaptive identifier system of anaerobic digestion process for sustainable biogas production.

1. Investigating the effect of processing parameters on the products of hydrothermal carbonization of corn stover

This investigation has focused on the effect of processing parameters on the products of HTC— namely solid fuel or hydrochar, liquid and gas fractions, and utilizing the produced corn stover hydrochar in AD process to increase biogas production. HTC was conducted in a temperature-controlled batch reactor with corn stover and deionized water under oxygen-free conditions obtained by pressurizing the reactor headspace with nitrogen gas. The properties of the hydrochar and liquid and gas fractions were evaluated as a function of the process temperature (250–350 °C), residence time (30–60 min) and biomass/water ratio (0.09–0.14).

Central composite design (CCD) modules in a response surface methodology (RSM) were used to optimize processing parameters. The maximum mass yield, energy yield and high heating value (HHV) of the hydrochar produced were 29.91% dry weight (dw), 42.38% dw and 26.03 MJ/kg, respectively. corn stover hydrochar produced at high temperature decreased biogas production while corn stover hydrochar produced at low temperature increased biogas production. Concentrations of acetic acid and hydrogen gas were 6.93 g/L and 0.25 v/v%, respectively. Experimental results after process optimization were in satisfactory agreement with the predicted HHV. The optimal HTC process parameters were determined to be 305 °C with a 60 min residence time and a biomass/water ratio of 0.114, yielding hydrochar with a HHV of 25.42 MJ/kg.

2. Development of an adaptive identifier system of anaerobic digestion process for sustainable biogas production

The corn stover hydrochar obtained from hydrothermal carbonization at a temperature, residential time, and biomass/water ratio of 215 ºC, 45 min and 0.115 respectively was added to the bioreactor as a substrate inoculated with food waste and cow dung to generate biogas. A state–space AD model containing one algebraic equation and two differential equations was constructed. All the parameters used in the model were dependent on the AD process conditions. An adaptive identifier system was developed to automatically estimate parameter values from input and output data. This made it possible to operate the system under different conditions. Daily cumulative biogas production was predicted using the model, and goodness-of-fit analysis indicated that the predicted biogas production values had accuracies of >90% during both model construction and validation.

3. Conclusions

This study demonstrates that corn stover can be converted to solid fuel through HTC. The corn stover hydrochar produced was compared with pulverized coal utilized in power plant. Using the adaptive identifier system indicated that data for at least 20 and 140 h were required to estimate stable parameters related to bacterial and substrate inputs, respectively. It is recommended to produced corn stover hydrochar at low temperature (100–200 °C) and residential time (10–30 min) to prevent inhibitor of methanogenesis, for increase production of biogas and utilize the hydrothermal process water in AD process.