博 士 論 文 の 要 約

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学 位 論 文 題 名

Torrefaction of high moisture content biomass using fresh dairy manure

(乳牛ふんを用いた高含水率バイオマスの半炭化)

Biomass is one of the major choices for alternative energy sources. However, certain drawback of raw biomass such as high moisture content sets the limitation of its use. Thus, pretreatment is necessary in order to remove the limitation. Torrefaction is an emerging technique for upgrading biomass. It is a thermal decomposition treatment used to convert biomass into a solid fuel. The conversion process is operated at low temperatures ranges from 200 ℃ - 300 ℃ under an inert atmospheric conditions. It will produce a solid fuel product called torrefied biomass, bio-char or bio-coal. Other names for torrefaction are slow and mild pyrolysis, high temperature drying as well as roasting. Generally, torrefaction can be achieved after successive stages of drying, post-drying, torrefaction and cooling. During the process, biomass is decomposed, oxygen is removed, and the fibrous structure and tenacity are destructed. These resultant characteristics give in the advantages of torrefied biomass over the non-torrefied biomass; torrefied biomass is more grindable and hydrophobic, contains high calorific value, and easily transported and stored. In general, torrefaction is conducted using dried or very low moisture content of feedstock. Also, inert condition is applied. However, there have been no reports on direct usage of high moisture content biomass as a feedstock during torrefaction. By using high moisture content biomass, the prediction for whole biomass degradation processes can be improved and beneficial to clarify the mechanism reaction mechanism of biomass torrefaction. In addition, a simplified approach by implementing torrefaction in non-inert condition can be adapted for real life scenario that offer low cost benefit. We believe these results can accommodate the underlying mechanism during the dairy manure torrrefaction.

This study aims to better understand the torrefaction process particularly on using high moisture content biomass from fresh dairy manure. Additionally, the research applies

limited oxygen condition for bioenergy production. Thus, the research question, hypothesis and objective in this research works are divided to three part where part one explained in chapter 3 and part two and three were described in chapter 4 in the thesis as follows;

PART 1

The advantages of torrefaction on biomass have been discovered. However, to the time this study was conducted, limited data have been published related with the direct usage of high moisture content livestock manure as a feedstock for torrefaction. In addition, there have been no information on wet manure torrefied through an industrial rotary kiln reactor.

i) Research question

   Is it possible to conduct a torrefaction with direct usage of high moisture content biomass?

ii) Hypothesis

   Wet biomass can be torrefied to produce solid product.

iii) Objective

   To investigate the capability of high moisture content dairy manure to become a solid product through torrefaction.

In this study, torrefaction for fresh dairy manure with 84.1% moisture content was carried out at three different temperatures (200 °C, 250 °C and 300 °C). For this purpose, an industrial rotary kiln combustion type reactor was used. As a result, wet dairy manure was converted to a solid product or torrefied manure. Due to its high moisture content, at least three cycles of non-continuous thermal treatment were required to complete the torrefaction.

PART 2

Due to non-continuous steps, the thermal reaction of torrefaction on high moisture content biomass could not be easily determined from the industrial rotary kiln combustion type reactor. Nevertheless, on the basis of characteristics and properties of the solid torrefied

manure, drying and thermal decomposition steps were strongly involved.

i) Research question

   Do drying and decomposition processes strongly involved in the torrefaction reaction of high moisture content biomass?

ii) Hypothesis

   Drying and decomposition of wet biomass can be determined through a continuous torrefaction.

iii) Objective

   To study the reaction mechanism of high moisture content biomass through a continuous torrefaction.

Hence, a continuous thermal degradation of high moisture content dairy manure was conducted using a laboratory oven. The weight loss profile data was collected and treated as a major source to understanding the reaction. In addition, gas production and sample temperature data were also collected. Resultants mass profile, gas production and sample temperature data confirmed that the torrefaction reaction involved a simultaneous process of drying and degradation. For a comprehensive prediction, we have developed a mathematical model for both process.

PART 3

In order to explain the high moisture content torrefaction reaction mechanism, a mathematical model is necessary.

i) Research question

   In what basis to develop the mathematical model?

ii) Hypothesis

   Mathematical model can be apply to predict the duration and decomposition of wet biomass.

iii) Objective

To develop a simple mathematical model for high moisture content biomass torrefaction.

Driven by the fundamental mass reduction data, the principle behind the mathematical model is to estimate the time for drying process to end. In summary, an analytical time scale model was develop from three period; preheating, decreasing and oxidation for the explanation of the reaction mechanism.

For part one, the research work has been published as ‘Torrefaction of high moisture content biomass in an industrial rotary kiln combustion type reactor’ in Journal of the Japanese Society of Agriculture Machinery and Food Engineers, 80 (2), 2018. For part two and three, the findings of this research work are under review for publication.