PRODUCT CHARACTERISTICS IN A PILOT SCALE BIOMASS TORREFIER WITH HEATED SCREW CONVEYANCE

Waste to Wisdom: Subtask 3.3

Biofuels and Biobased Product Development

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Abstract

This thesis investigates the parameters impacting product quality in a pilot scale biomass torrefaction reactor. The system analyzed in this work was designed and manufactured by Norris Thermal Technologies for use in Big Lagoon, California at a remote mill site. The torrefaction unit was a continuous feed reactor with an electrically heated screw, which served the dual purpose of heating and biomass conveyance. Data was collected during the summer of 2015 as a part of the Waste to Wisdom project, funded by the U.S. Department of Agriculture and Department of Energy. The goal of the interdisciplinary Waste to Wisdom project, to which this thesis research will contribute, is to investigate the economics, life cycle costs and benefits, and energy efficiency of using biomass conversion technologies to improve the value of waste wood for the energy market.

Forest residues which are currently left on hillsides or burned, can be transformed through the thermochemical process of torrefaction into energy rich fuel sources. The data collected as a part of this research included information about variation in the feedstock species and moisture content, as well as the controllable parameters of the torrefaction reactor itself, including temperature set point and residence time. Feedstocks tested in this study included douglas fir, redwood, tan oak, and hardwood "slash," a combination of tan oak and other unfiltered hardwood with bark and branches. The residence times tested during the experiments were 6 minutes and 8 minutes, and the input moisture content range for the experiments was 3% to 35% on a wet mass basis. The product characteristics studied were the torrefied solid mass yield, an indicator of the severity of torrefaction, the energy yield of the process, and the enhancement of the wood's higher heating value from inlet to outlet. Additionally, design recommendations were made for scaling up the pilot torrefaction unit into a larger full scale unit for testing in the summer of 2016.

The energy and mass yields were found to be highly correlated in this analysis. As expected, as the mass yield decreases, indicating an increased degree of torrefaction, the energy yield also decreases, but on average it only decreases by 0.89% for every 1% the mass yield loses. This result shows that the energy content decreases at a slower rate than the mass yield through the torrefaction process, resulting in a less massive but more energy dense solid product. The best predictor of both energy and mass yield in this study was the steady state temperature measurement in the biomass product closest to the outlet of the reactor. This temperature explained 33.9% and 49.6% of the variation in the energy and mass yield data respectively. The variation in residence time, moisture content and feedstock species are not statistically significant parameters for predicting mass yield and energy yield, and therefore control of these parameters is less important than accurate control of the temperatures inside the reactor. The enhancement factor showed a similar dependence on

temperature, however this product characteristic also depended on the feedstock species. The enhancement of the higher heating value on average was greatest for tan oak, next largest for slash and redwood, and smallest for douglas fir.

The screw set point temperature was discovered to have an inaccurate thermal response due to the self heating of the thermocouple probe, resulting in a recommendation to electrically insulate the thermocouple in the full scale reactor. Additionally, improved airlock sealing ability and continuous nitrogen purge in the reactor chamber were recommended for control of the inert atmosphere in the reactor to reduce the opportunity for unwanted combustion. Air leakage into the reactor is likely related to unexpected thermal response along the reactor. Future work is underway to analyze the chemical composition, grindability and hydrophobicity of the product biomass as well as a comprehensive analysis of the energy and mass balances.