The Fact sheet

R&D to Prepare and Characterize Bio-char/carbon From Undervalued Lignocellulosic Biomass for Bio-product Applications

Background:
Food security, climate change and energy sustainability are the three major challenges in the 21st century. Among different renewable energy sources, bio-energy is one of the renewable primary energy sources, touching all three major issues due to its competition with food on land use, low net CO2 emissions and potentially sustainable if the economical, environmental and social impacts are properly managed. The targeted research looks to develop and evaluate new or improved technologies to overcome technical hurdles associated with the conversion of Canada’s particular range of low grade biomass resources. These resources range from woody biomass to agricultural and municipal wastes. Various challenges presently exist, which limit the economic viability and operational reliability of conversion processes for these types of fuels. Collectively these feedstocks have tremendous potential for the production of fuels (ethanol, syngas, torrefied biomass) and chemicals using gasification and Fischer-Tropsch chemistry.

The Ontario Ministry of Environment (MoE) is committed to supporting the environmental research by establishing Best in Science program. One of the priorities of the program is to support research through grants that involve active alliances amongst institutions on projects that support Ontario’s current environmental priorities and current or future environmental needs. One of the such priorities is "Local Air Quality and Climate Change – Greenhouse Gas Reduction". Similarly, the Bio-renewable innovation lab (BRIL) at School of Engineering of University of Guelph is committed to developing an innovative research program on energy and other value-added products from biomass and waste materials. The ultimate focus of BRIL is making use of biomass resources to produce affordable power, fuels, and chemicals by exploring new methods that are more environment friendly than those presently available. The BRIL has partnered with MoE to prepare and characterise biochar/carbon from undervalued lignocellulosic biomass for bio-product applications.

Project Description:
The research team investigates various types of biomass feedstocks (miscanthus, willow, poplar, wheat straw, corn husk, corn cobs, and tomato vines) to hydrothermal carbonization (HTC), creating a densified coal-like product by exposing biomass feedstocks to heat and pressure in the presence of water. Products are analyzed to examine the effect of operating conditions on the physicochemical properties of biomass. This proposal explores in understanding several unanswered questions: Can we produce solids fuels (biochar/biocarbon) from low quality lignocellulose biomass that will have similar properties of coal specially low alkali metal, higher HHV and grindability? If so, can we develop an scalable continuous process based on this investigation? What is the scientific principle underlying such improved behaviour of the product?

For comparison, torrefaction (a conventional thermal pre-treatment) was also applied to the miscanthus feedstock. The solid product from both the thermal pre-treatments was investigated for the densification characterization. The liquid by-product from the HTC process and its effects of recirculation was also analyzed in this study. Three sub-objectives (as presented in objective section) are proposed, each of which can contribute directly or indirectly to greater efficiency towards commercialization and reduced greenhouse gas emissions.

Objectives:
The overall objective of this proposal is to carry-out fundamental research on development of renewable resource-based energy and fuel and their value-added product, from Canada’s particular range of low grade lignocellulosic feedstocks. These feedstocks range from woody to agricultural biomass and municipal wastes. In particular, the project aims to:

- produce biochar/biocarbon from wet agricultural and low grade biomass feedstocks through hydrothermal (HTC) processing technology
- characterize HTC biochar for different applications and compare those with biochar produce through pyrolysis and torrefaction, and
- develop boundary for each unit operations and its materials and energy balances for conducting life cycle assessment (LCA).
Accomplishments:
The work performed in this study demonstrated the potential of HTC of biomass for the production of carbon-rich solid fuel, known as hydrochar that has significantly improved combustion characteristics. A bench scale reactor is developed and utilized to perform HTC processing of various types of biomass to produce hydrochar.

In comparison, the physicochemical properties of solid produced via torrefaction (a conventional thermal pre-treatment) were considerably less favorable than the hydrochar samples, even if the reaction time was kept much higher than HTC. Both raw and pre-treated biomass was further studied for densification characterization. The HTC pellets show significantly improved durability, mass and energy density, and hydrophobicity compared to raw and torrefied pellets. The result shows that HTC narrows the differences in fuel qualities and has potential to replace coal in existing coal-fired power plants without any significant modifications. In conclusion:

- HTC pretreated biomass shows improved grindability and reduced ash yield.
- Energy density and O/C–H/C ratios of HTC-260 C pellets are comparable to lignite.
- HTC pellets show improved hydrophobicity and resistance against water immersion.
- Torrefied pellets show low mass density and durability even compare to raw pellets.
- Liquid water HTC required 1/3 the heating energy compared to vapor HTC.
- Liquid water HTC reduced potassium content of corn husk by 90%.
- Liquid water treated hydrochar produced the most coal-like combustion performance.

Benefits:
This project will broaden the utilization of carbon-neutral biomass, which will extend our energy resources, increase energy security, and directly address pressing environmental concerns by reducing fossil-based energy production carbon emissions.

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