Characterization of Crop-Waste Biochar: An Investigation into Converting Biowaste into a Bioresource for the Developing World

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Abstract

Biochar (BC) is a carbon-rich and porous material capable of adsorbing chemical constituents from water, air, and other media. As such it is an alternative water filtration option comparable to activated carbon. It is produced through the pyrolysis of biomass. Cotton Hull and Pecan Shells crop-waste were synthesized into BC through Top-Lit Updraft (TLUD) and Muffle Furnace (MF) pyrolysis to demonstrate the difference between controlled (industrial) and uncontrolled (developing world) pyrolysis. Their chemical and physical properties have been characterized through the use of XRD, FTIR, TGA, DSC, SEM, and BET surface area analytical tools.

The comparisons between the pyrolysis process and biomass show that a BC synthesized in the developing world would have characteristics similar to an industrially produced BC. Both BCs possess a porous structure and active functional groups that make them an excellent candidate as a filter or membrane for the removal of pollutants from water. The fact that a quality BC sorbent, as shown in this can study, can be made from commonly found crop waste through inexpensive and simple pyrolysis techniques demonstrates its usefulness and ease of implementation in a developing world setting.

Introduction

- Access to clean water is an issue that persists in much of the developing world. Available water is often polluted from inadequately treated agricultural, industrial, and human wastes.
- Employing water protection and water treatment strategies in the developing world is often challenging due to a lack of financial resources, industrial infrastructure, and technical know-how.
- BC is a cheap and easily accessible water treatment option as it can be easily synthesized through the pyrolysis of virtually any organic material.
- TLUD and MF pyrolysis were utilized to simulate a developing world and an industrially created BC respectively. Their physical and chemical characteristics were compared to determine if there is a loss in effectiveness.

Methods and Materials

- The type of biomass and pyrolysis affects the overall characteristics of the BC. Pecan Shell and Cotton Hull crop waste were characterized under two different pyrolysis processes.
- A TLUD pyrolysis device was created with easily obtained materials.
- MF pyrolysis mimics industrial processes while TLUD is what would be utilized in the developing world.
- The differences between the biomasses and pyrolysis processes have been characterized and compared.

Analytical Device	Purpose
SEM/EDX	Morphology and Elemental Analysis
BET Surface	Determine Specific Surface Area
PXRD	Identify Phases, Crystalline/Amorphous, and Composition
TGA/DSC	Determine Mass Loss, Enthalpy, Reaction Kinetics, Phase Change
FTIR	Identify Organic, Polymeric, or Inorganic materials

Raw Cotton Hull

Raw Pecan Shell

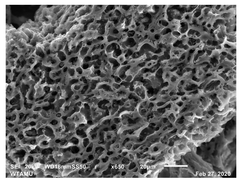
TLUD Device

Muffle Furnace

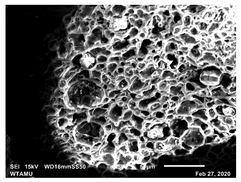
SEM/EDX and BET

- The porous nature of BC is a major factor in adsorption capability. Pores contribute to the overall surface area creating additional adsorption sites.
- Pores are visible on the BC SEM images and the additional surface area is given by BET.

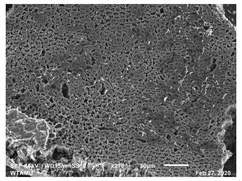
Biochar Type	BET Surface Area (m^2/g)
TLUD Pecan Shell	428.652
MF Pecan Shell	43.092
TLUD Cotton Hull	555.996
MF Cotton Hull	489.753



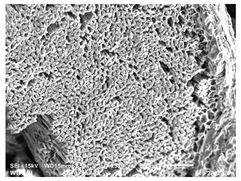
TLUD Pecan



MF Pecan



TLUD Cotton



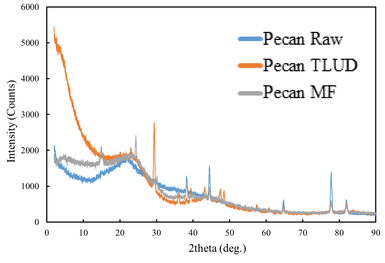
MF Cotton

Element	Mass %			
	TLUD Pecan	MF Pecan	TLUD Cotton	MF Cotton
C	74.420	73.320	82.060	74.720
O	20.230	26.140	12.240	21.920
Mg	2.690	X	1.860	0.910
P	0.310	X	X	X
K	1.070	0.230	3.840	2.450
Ca	1.280	0.310	X	X
Total	100.000	100.000	100.000	100.000

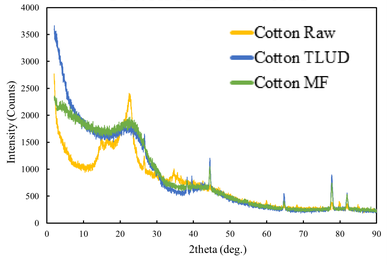
XRD

- XRD analysis of the biomass and indicate these materials are noncrystalline (amorphous).

Pecan XRD Patterns

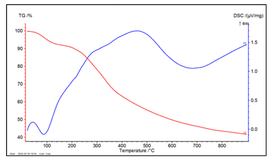


Cotton XRD Patterns

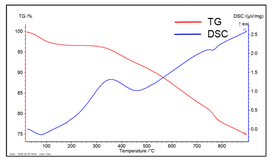


TGA/DSC

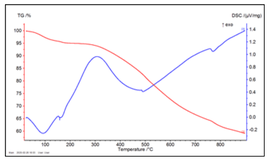
- TGA/DSC analysis indicate that the raw biomass and BC undergo pyrolysis at around 260°C and 340°C, respectively. This indicates a higher thermal stability of biochar and a greater availability of oxidizer in the raw materials.



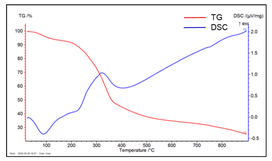
RAW Pecan



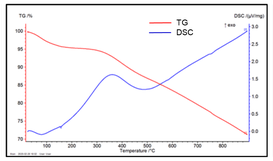
TLUD Pecan



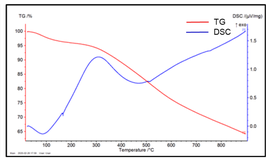
MF Pecan



RAW Cotton



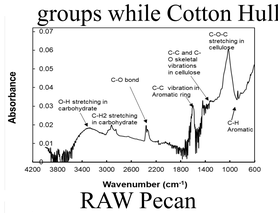
TLUD Cotton



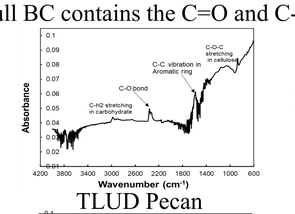
MF Cotton

FTIR

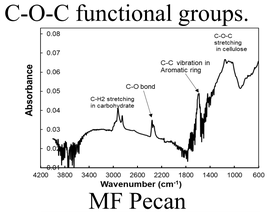
- Analysis indicate the presence of O-H, C-H, C-C, CH2, C-H, and C-O-C functional groups in the cellulose structure of the raw material.
- Pecan Shell BC predominantly contains the CH2, C=O and C-O-C functional groups while Cotton Hull BC contains the C=O and C-O-C functional groups.



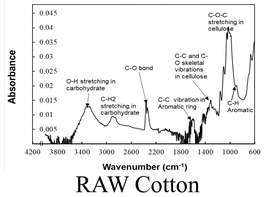
RAW Pecan



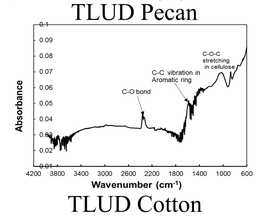
TLUD Pecan



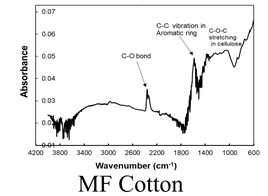
MF Pecan



RAW Cotton



TLUD Cotton



MF Cotton

Conclusion

As shown by the analyses TLUD BC is comparable to MF BC and provides a larger surface area and thus more adsorption sites. Cotton Hull BC has a larger surface area than Pecan Shell BC This presence of a porous structure and active functional groups in biochar makes them an excellent candidate as a filter and membrane for the removal of pollutants from water.