ROTARY COMPRESSION UNIT: A NOVEL TECHNOLOGY TO PRODUCE BIOCHAR IN A CONTINUOUS STATE USING VARIOUS BIOMASS STREAMS

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Introduction

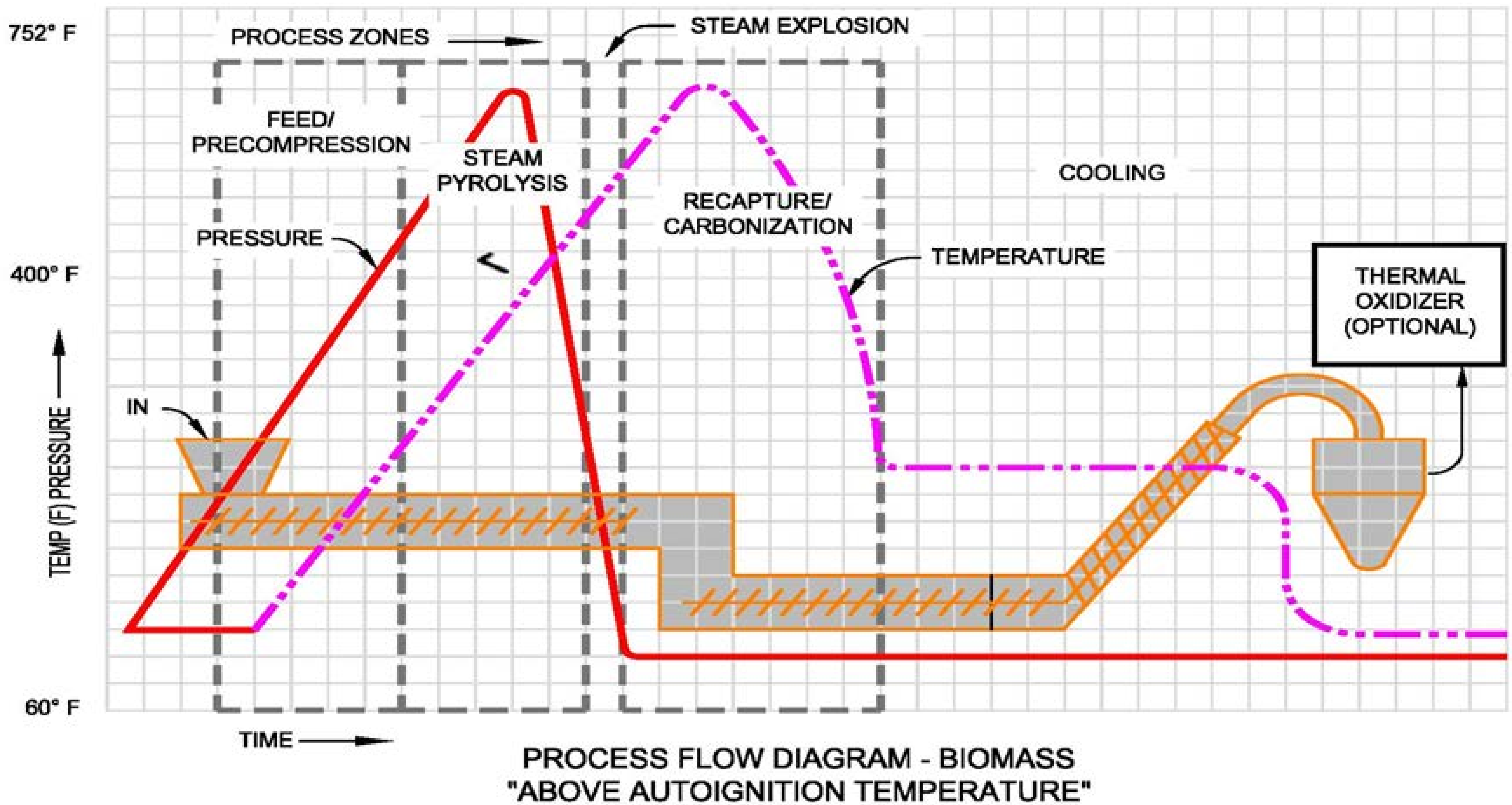
- Enginuity Worldwide, LLC headquarters located in Mexico, Missouri

The Enginuity Process

- Consists of a Rotary Compression Unit (RCU), a Reflux Condenser, and an Aftercooler
- No external heat source is required
- Continuous process may be carried to char in under 5 minutes
- Capable of processing sources of wood, nut shells, grass, stovers, AD, and animal wastes.

Figure 1: Before treatment (L) and After (R): Corn Stover biochar

Process Flow



Rotary Compression Unit

Figure 2/3: The 6” RCU with Reflux Condenser and Aftercooler

The 12” Rotary Compression Unit

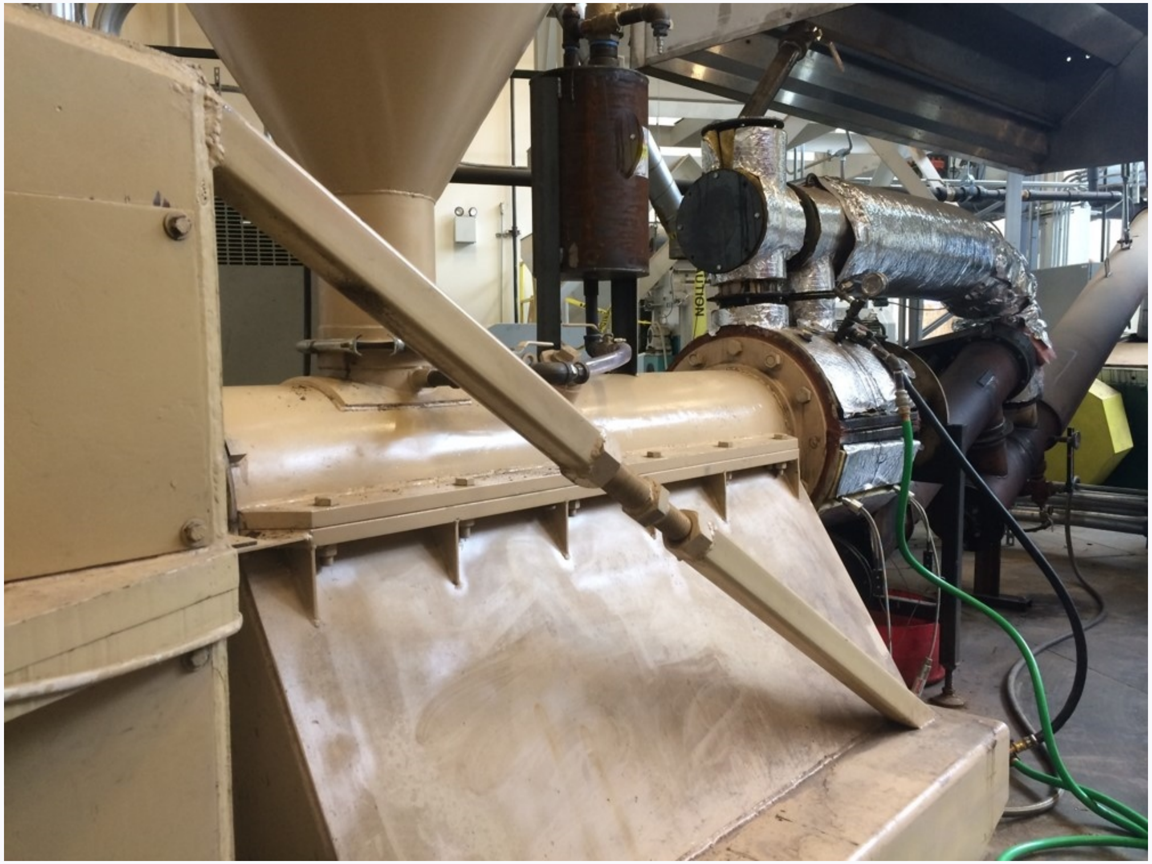


Figure 4: the 12” Rotary Compression Unit prototype

Analysis of Biochar

Figures 5/6: Germination testing of EWW biochar with lettuce seeds. Group of 25.

- Testing Includes:
  - Proximate analysis
  - Elemental analysis
  - Porosity analysis
  - Water capacity
  - Germination Assay
  - Growth Studies

Growth Studies

- Series of experiments analyzing:
  - Aged vs. fresh
  - 1% vs. 5% addition
  - Comparing EWW's biochar to another commercial biochar
  - Comparing EWW biochar to potting soil

Figure 7: Previous growth study. A1 group was control with potting soil only; D1 was 10% biochar to soil

Growth Studies

- Pea plants used in growth study
- Potting soil used as a negative control
- Biochar was hardwood and was analyzed at 0 week aging (charging), 1 and 2 week aging with cow manure compost
- Monitored:
  - Moisture
  - pH
  - Temperature
  - Growth Rate (including germination)
  - Plant Height

Growth Studies

- 1% and 5% by volume was analyzed
- Biochar top dressed on soil and then tilling was mimicked
- This procedure repeated for the aged char samples

Figure 8: 5% EWW biochar sample (Mid) and potting soil (L) and 1% EWW biochar

Results

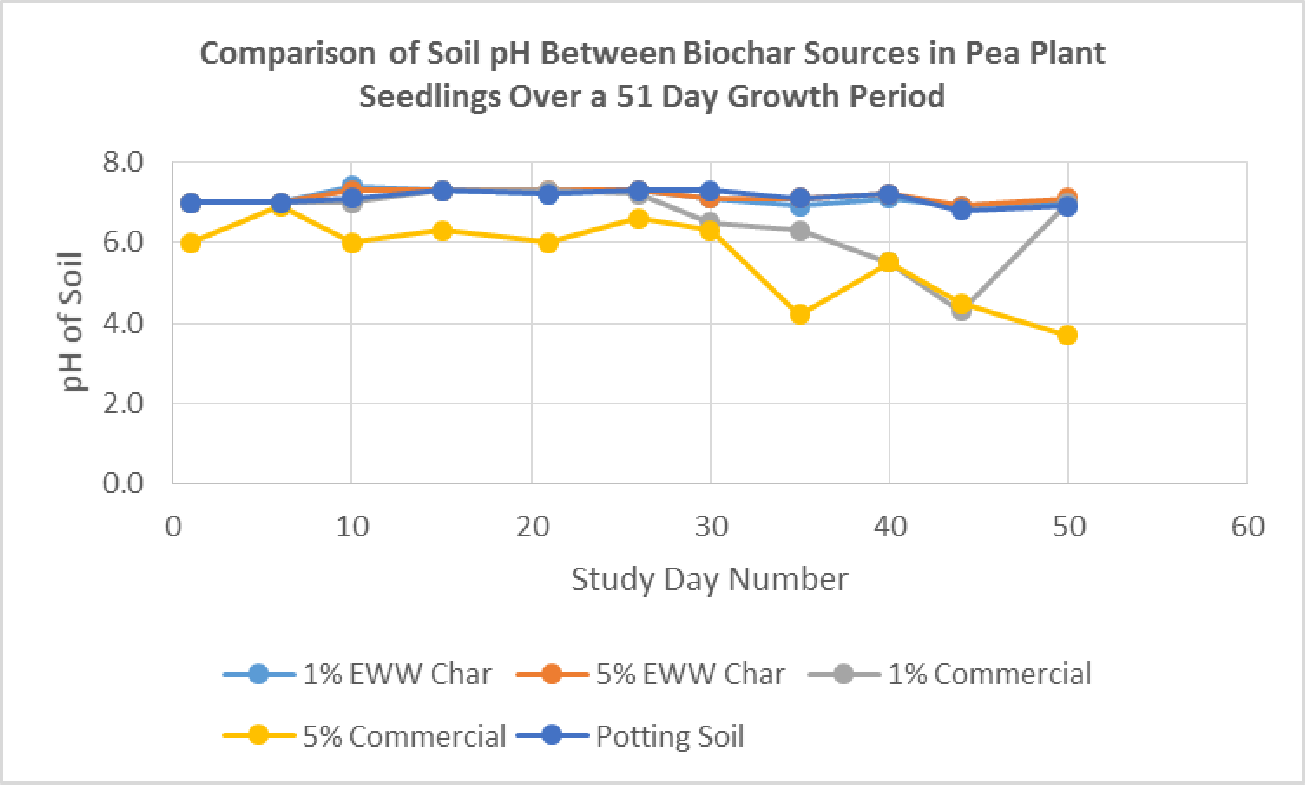
- EWW biochar maintained a **steadiest pH and moisture content** over the length of the study

- 5% EWW biochar produced the **greatest growth rate and plant height** in the 0, 1, and 2 week trials

- The EWW biochar produced **more robust plants** in regards to breakage
  - At 24 days of experiment, plants in potting soil group, manure group, and char control group began breaking
  - By days 36-50, almost all of them were broken, while EWW remained intact

- EWW biochar aged for two weeks in manure compost **improved germination rate of seeds by one day**

Figure 9: Soil pH of the unaged char group



- pH fluctuations can cause growth issues as well as brown spotting
- Low pH leads to H+ toxicity which releases manganese and aluminum at toxic levels
- High pH leads to molybdenum toxicity and stunted growth

Results

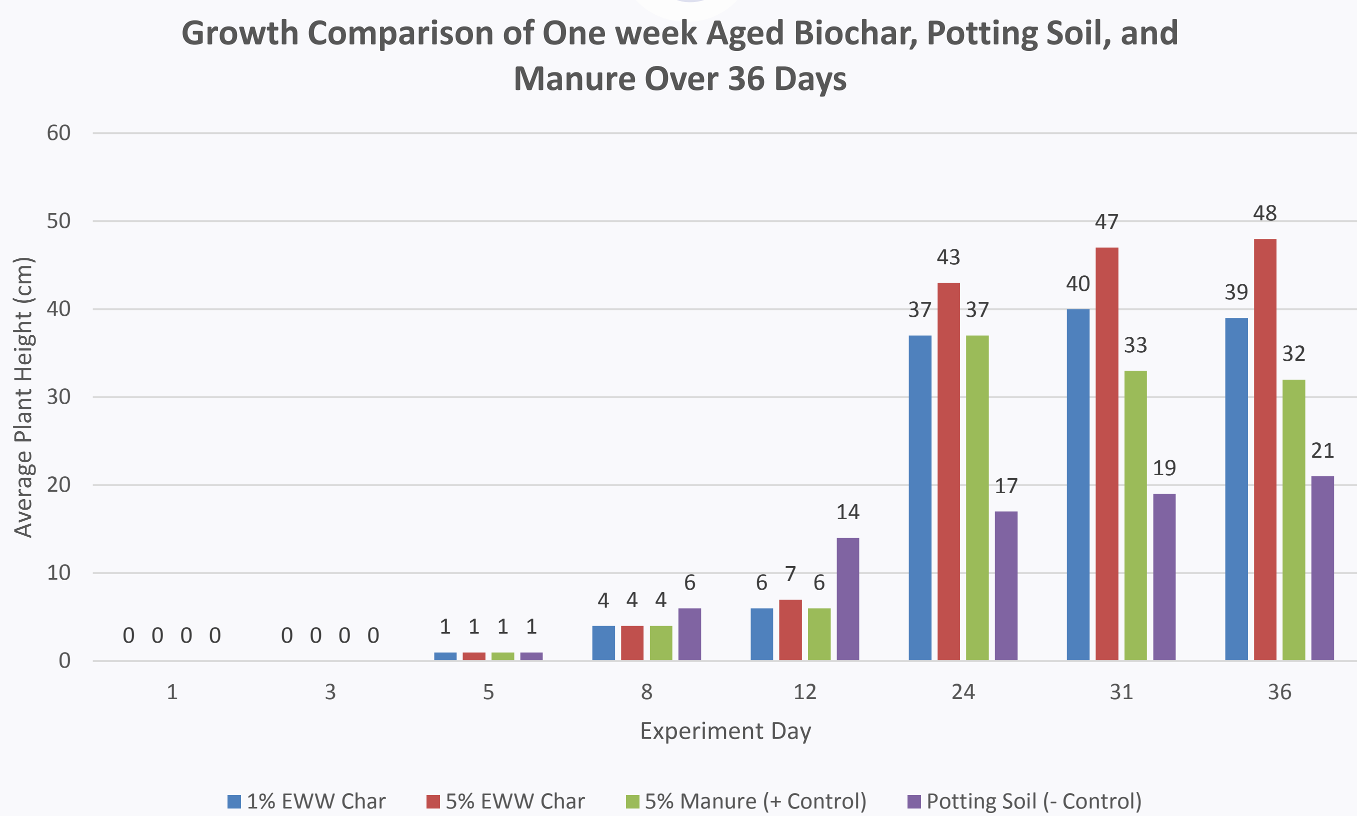


Figure 10: Growth of the 1 week aged biochar over 36 days

Results

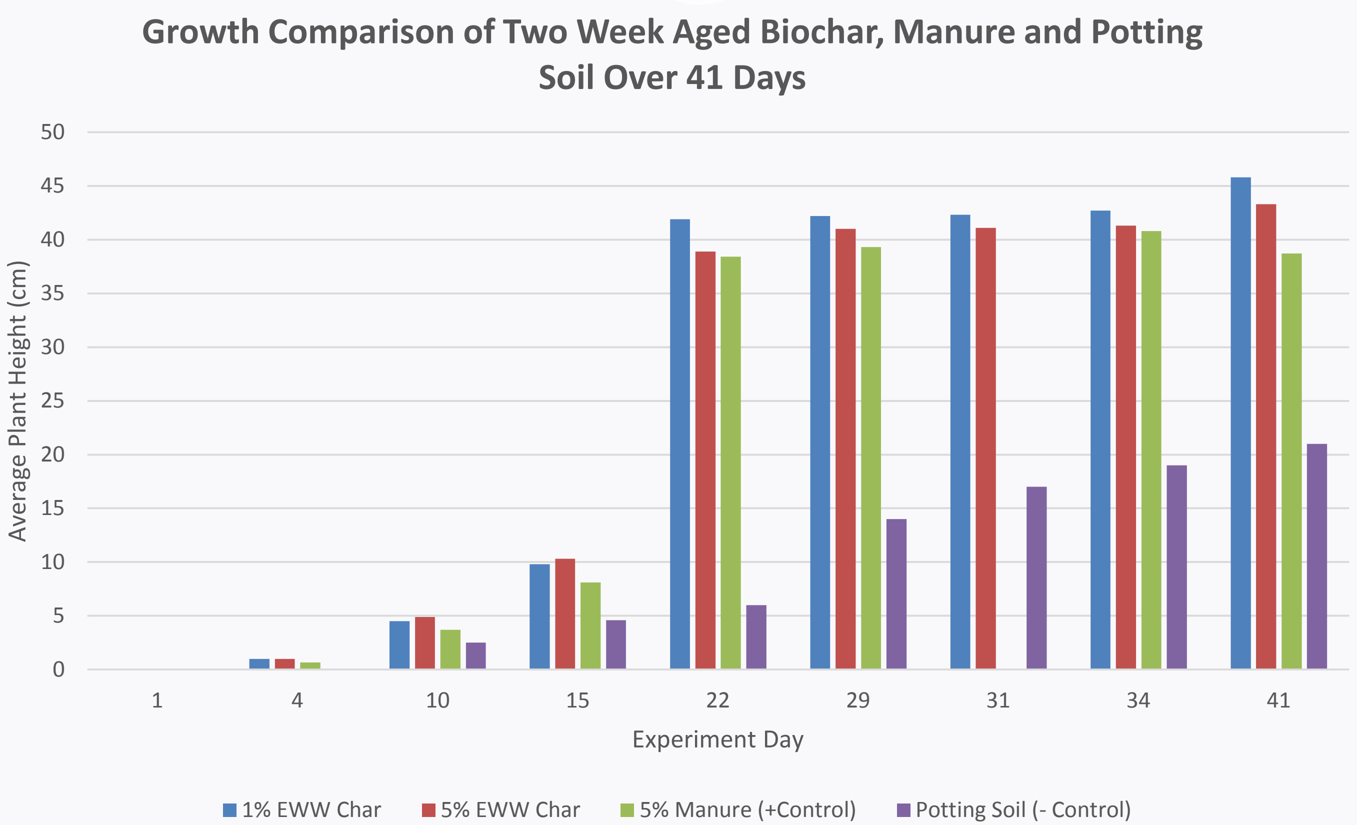


Figure 11: Growth of the 2 week aged biochar over 41 days with positive and negative controls

Characteristics of EWW Biochar

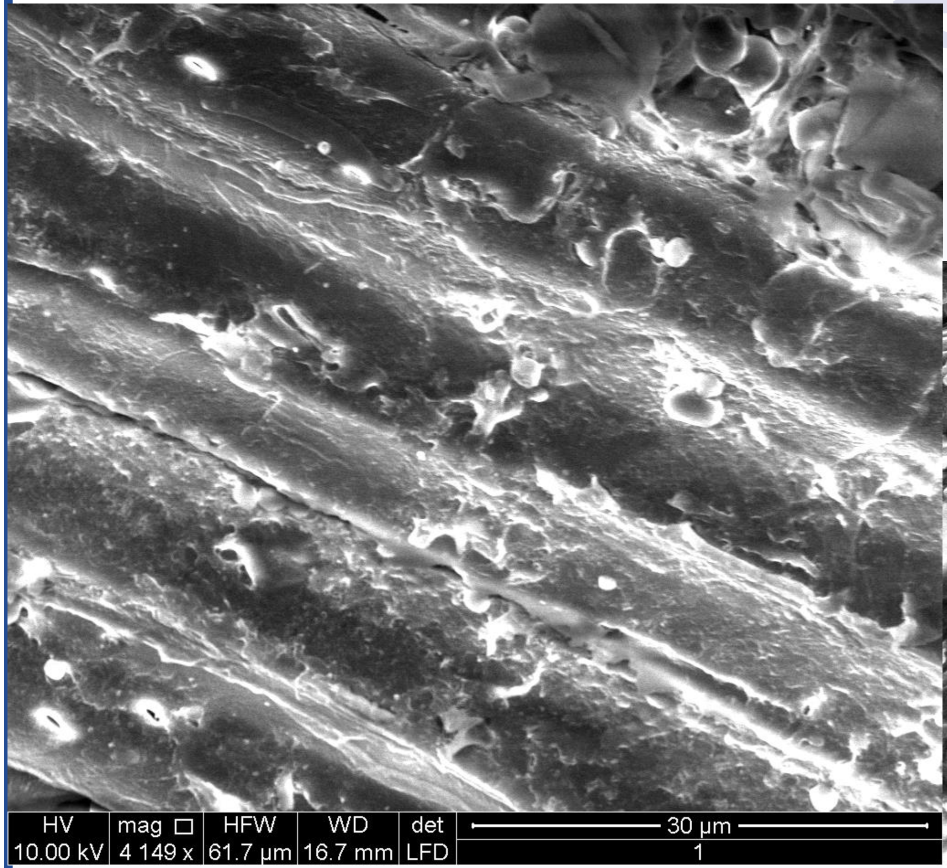
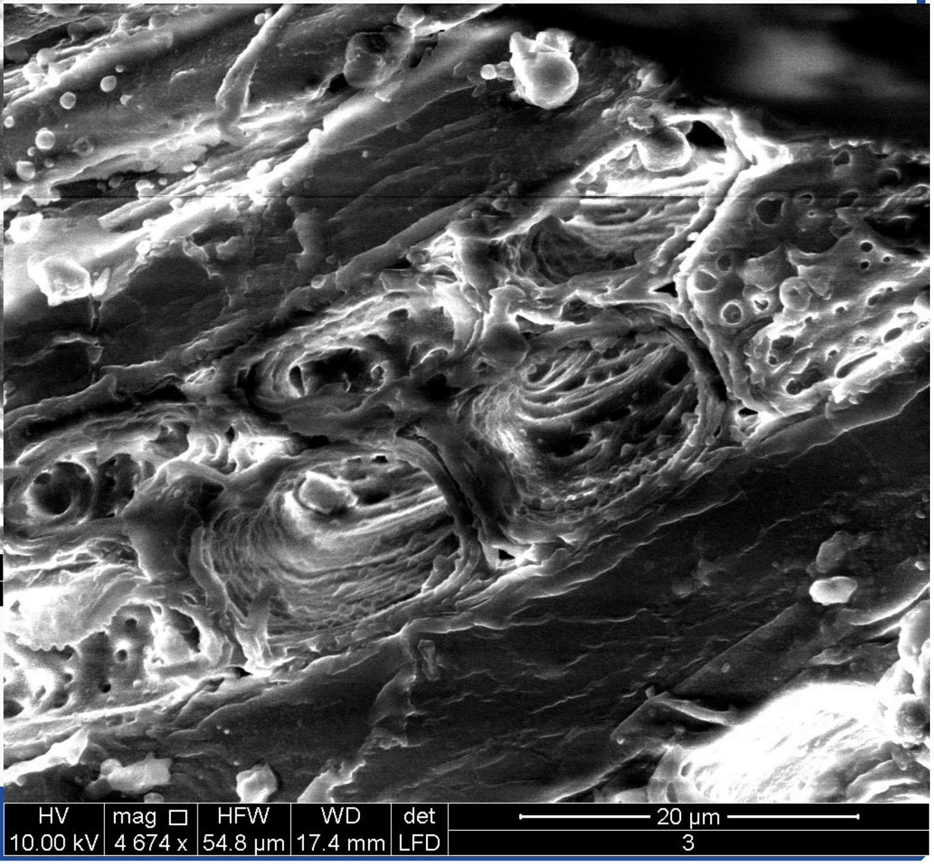


Figure 12: SEM image of unprocessed oak at 4149X magnification

Figure 13: SEM image of BioCoal oak at 4674X magnification



Characteristics of EWW Biochar

	Corn Stover Biochar	Hardwood Biochar
Carbon (wt.%)	54.13	56.6
Hydrogen (wt.%)	4.63	5.53
Nitrogen (wt.%)	1.09	0.2
Oxygen (wt.%)	27.89	36.39
Volatile Matter (wt.%)	53.91	69.88
Ash (wt.%)	12.16	0.96
H/C	1.03	1.17
C/N	57.94	330.17
O/C	0.39	0.48
pH	6	6.7
Water Holding Capacity (% of char's weight)	308%	344%
Germination Success (% germination of 25 seeds)	96%	92%

Table 1: Data with third party validation of two biochars

Characteristics of EWW Biochar

- Explosive decompression disrupts fibrous structure of lignocellulosic material (steam explosion)
- Results in highly porous material
- Porosity tested via Mercury intrusion porosimetry, a variation of the BET method

Sample	Median Pore Diameter (um)	Difference (%)
Untreated Corn Stover, 1/4" minus	24.2181	-
Stover treated at 200F, 1/4" minus	111.9039	362.07

Table 2: Porosity analysis of processed corn stover using Mercury Porosimetry

Figure 14: Pyroligneous Acid/BioOil

Figure 15: BioCoal Briquettes

Figure 16: Untreated wood (L) and BioChar (R)

The Enginuity Process

- No external heat source is required
- Continuous process may be carried to char in under 5 minutes
- Capable of processing multiple biomass streams

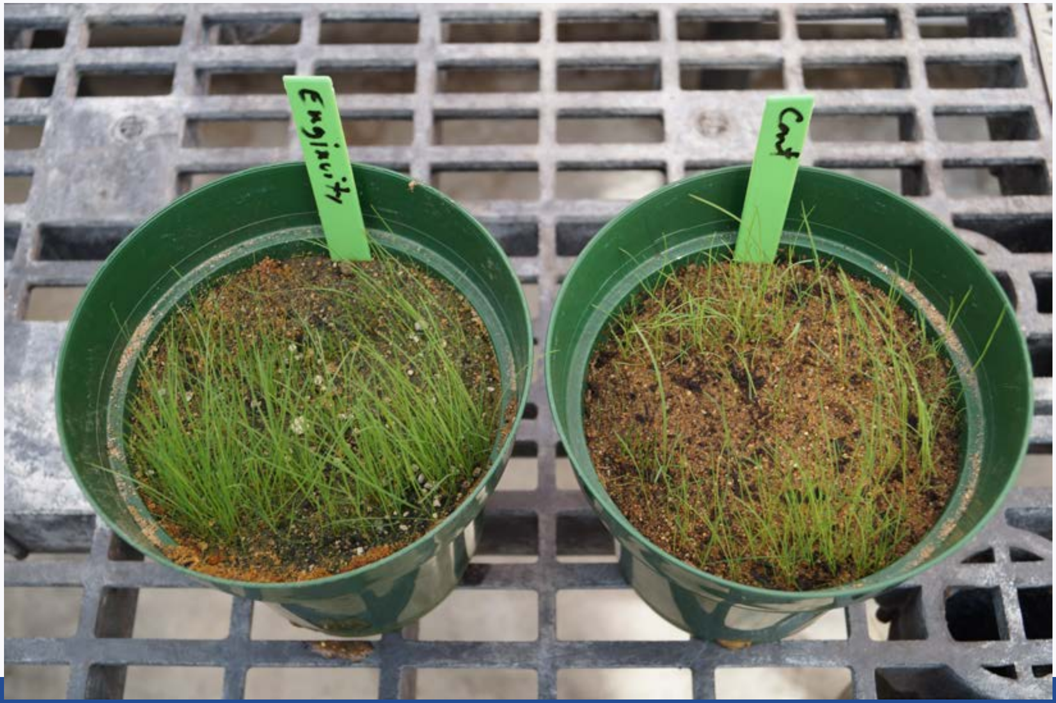


Figure 17: EWW biochar (L) and Control (R). Using Creeping Bentgrass. Photo courtesy of Dr. Vaughn of the USDA-ARS lab in Illinois.

Feedstocks Processed

- Corn stover
- Grasses
- Miscanthus
- Oak
- Pine
- Mesquite
- Pallet Lumber
- Juniper
- Poultry Litter
- Manure
- Exotics
- Pecan shells
- Fescue
- Anaerobic Digestate Material
- Paper and Pulp Waste

Figure 18: Anaerobic Digestate after processing

Figure 19: Cone flowers with biochar. Relocated at least once

Figure 20: Cone flowers without biochar. No relocation.

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Introduction to frictional pyrolysis (FP) – An alternative method for converting biomass to solid carbonaceous products

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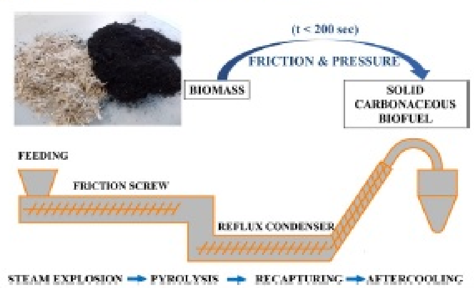
HIGHLIGHTS

- Introduction of a novel method of pyrolysis via friction and pressure.
- The process time is less than 200 s.
- The final solid yield is higher than 80% and has 96% of the initial energy content.
- The net energy balance is 92.2% on HHV basis.
- The product has increased fixed carbon content in comparison to torrefied biomass.

GRAPHICAL ABSTRACT



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ABSTRACT

In the biomass sector, technologies like carbonization and torrefaction have been utilized for the production of solid carbonaceous biofuels and materials. In the framework of this manuscript a novel method for production of solid carbonaceous materials is introduced and is defined from now on as frictional pyrolysis. It uses only the application of pressure and friction whereas no external heat transfer is needed for the propagation of the process. This novel method is compared with torrefaction in order to assess its potential to process corn stover which has strongly bounder water and high content of deciduous xylan. Mass balances have been implemented for both technologies. Characterization of the products has been done by means of Simultaneous Thermal Analysis and Elemental analysis. Frictionally pyrolyzed corn stover has higher recovered mass yield, higher recovered energy yield and fixed carbon content than torrefied corn stover. Although external energy is provided by means of an internal combustion engine the net energy content of the final solid yield contained 92.2% of the input energy. The differential scanning calorimetry analysis showed that under the same heating rate regime and in oxygen-rich environment, the frictionally pyrolyzed corn stover had more exothermic decomposition than the torrefied material.

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