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# Detection of Biochar Components for Soil Fertility using THz-TDS

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**Abstract**—Different forms of biochar can have greatly different properties as fertilisers, yet there is no effective screening method to distinguish them. Terahertz Time Domain Spectroscopy has been used to distinguish various biochars, including Sawdust char, BMC5 with lime char and Saligna char.

## I. INTRODUCTION AND BACKGROUND

Biochar has a potential of becoming an effective fertiliser for variety of crops, without harmful side-effects of chemical fertilisers. Different forms of biochar have been tested: some of them showed a strong (20% for corn<sup>1</sup>) increase in crop yield. Benefits of biochar are also predicted to include greenhouse gas reduction from carbon sequestration and an increase in water quality.<sup>1</sup> Farmers using biochar would use less fertiliser and have less nitrogen and phosphorus rich runoff from fields. A recent report<sup>2</sup> identified the need for a rapid screening technique that would enable comparison of properties of different biochars and their matching to a particular use as one of the research priorities. Terahertz Time Domain Spectroscopy (THz-TDS) has been proven as a successful technique for detection of molecules in various types of materials, ranging from glass<sup>3</sup> to more complex samples such as explosives and cancer tissue. This makes it a promising candidate as the technique enabling distinction of different forms of biochar, promoting further research into this area for the benefit of greater crop productivity.

Currently methods such as Mid-Infrared Spectroscopy with partial least squares<sup>4</sup> can estimate soil fractionations. Methods exploring biochar such as; x-ray diffraction, synchrotron near-edge x-ray absorption, and Fourier Transform Infrared, all display chemical transitions at distinct wavelengths. However whilst these may show small shifts in the peaks with different (100-700°C) temperatures, all methods show very small differences in grass char from wood char.<sup>5</sup> Most methods, with NMR being the exception, are unable to quantitatively distinguish different origins of Char (or their types). THz-TDS provides very different absorption profiles for different chars. This is because terahertz provides information on low frequency bond vibrations and crystalline phonon vibrations in solids rather than high frequency bond vibrations detected using Infrared. THz-TDS also offers a cheaper, less time consuming method than NMR spectroscopy<sup>4</sup>.

## II. METHOD

Experimental equipment and procedure used are typical for THz-TDS and can be found in [6].

## III. RESULTS

Spectra in the time domain have been taken for three different biochar initial samples of thickness 4 mm. Saligna char was the only sample of 4 mm thickness not to greatly absorb the THz radiation at higher frequencies. The small main peaks of sample thickness 4 mm were used to find the refractive index of the samples Sawdust and BMC5. The measurements were then performed on thinner samples of unknown thickness on sticky tape. The thickness was then determined from the first measurements' refractive index and the peak positions of the sample and reference scan in the second measurement. Gaussian curves were fitted to these peaks and the thickness determined from the following equation:  $d = \frac{(Peak1 - Peak2)c}{n - 1}$ , where *Peak1* is the position

of the Gaussian peak of the sample (in seconds), *Peak2* is the position of the Gaussian Peak of the reference (in seconds), *c* is the speed of light (ms<sup>-1</sup>) and *n* is the refractive index.

The three char refractive indices are comparable within these. The refractive index cannot distinguish char type.

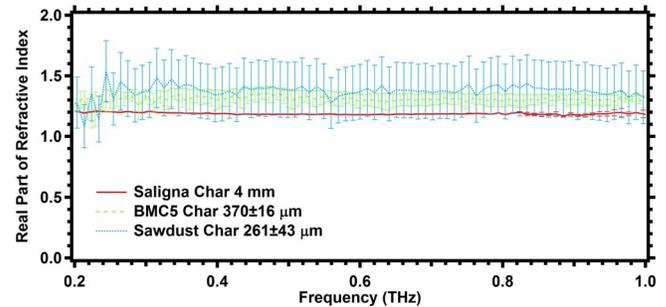


Fig. 1. Refractive index comparison of Saligna, BMC5 and Sawdust.

When the absorption coefficient ( $\alpha$ ) is calculated from these THz-TDS measurements, the distinction between the three different biochar samples becomes obvious. This can be seen in Fig. 2.

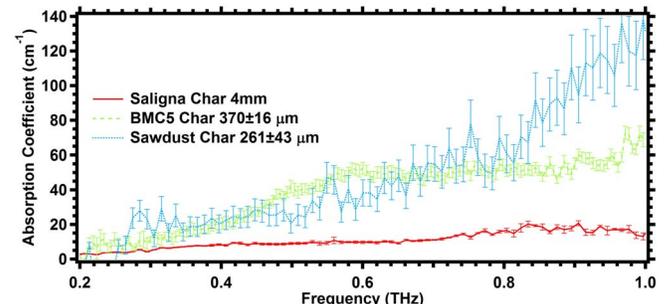


Fig. 2. Absorption coefficient as a function of frequency of Saligna, BMC5 and Sawdust char.

All three samples differ in terms of the amplitude and frequency dependence of  $\alpha$ . Saligna and BMC5 have two peaks, but at different frequencies. Sawdust biochar exhibits only a monotonous increase of  $\alpha$  with frequency. These results demonstrate the potential of THz-TDS as a new technique to distinguish different types of biochar.

Another commonly used parameter is the extinction coefficient (Fig. 3) which clearly shows differences in all 3 samples.

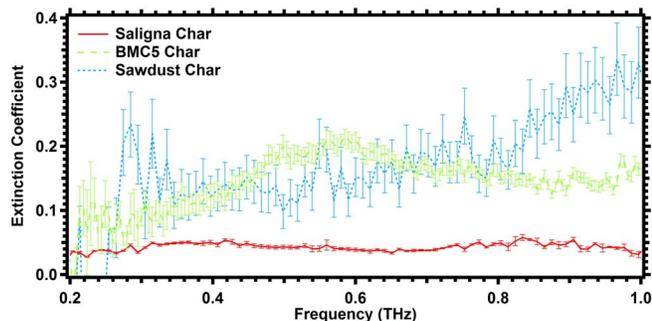


Fig. 3. Extinction coefficient as a function of frequency of Saligna, BMC5 and Sawdust char.

There is a peak at 0.52 THz and 0.58 THz for BMC5 Char. Saligna Char shows two peaks at 0.40 THz and 0.85 THz. The Sawdust Char again shows a steady increase with no peaks from 0.2-1 THz. Fig. 4 below shows Saligna Char's extinction coefficient peaks clearly.

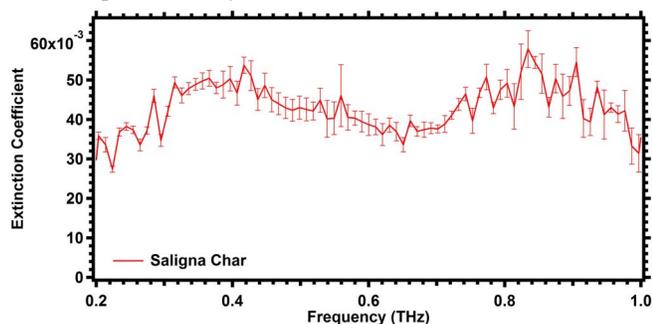


Fig. 4. Extinction coefficient as a function of frequency for Saligna char.

Continuous wave THz methods may also be used to distinguish between samples at 0.6 and 0.9 THz.

The percentage absorbed, reflected and transmitted is displayed for each sample in Fig. 5-7.

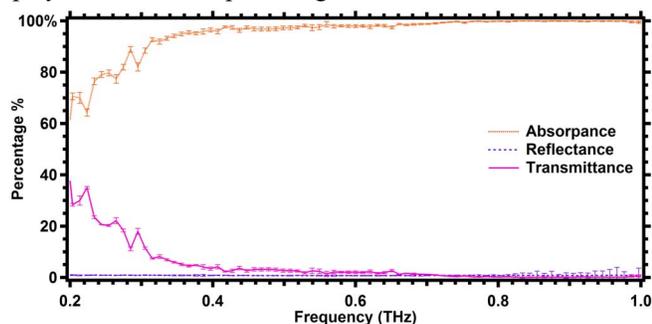


Fig. 5. The absorbance, reflectance and transmittance of Saligna char (thickness 400  $\mu\text{m}$ ).

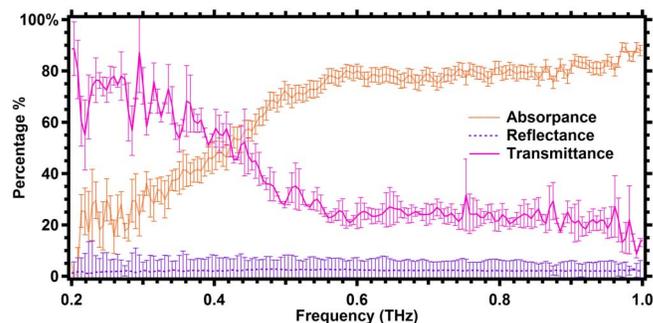


Fig. 6. The absorbance, reflectance and transmittance of BMC5 char (thickness 370  $\mu\text{m}$ ).

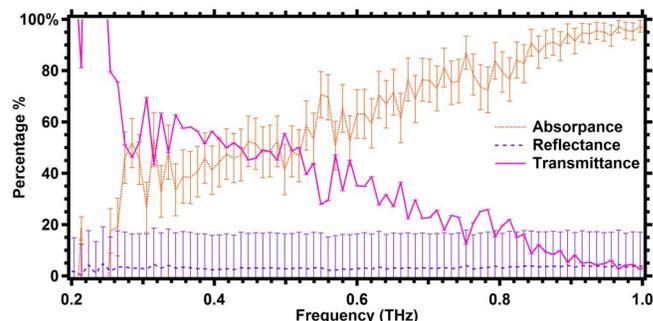


Fig. 7. The absorbance, reflectance and transmittance of Sawdust char (thickness 261  $\mu\text{m}$ ).

#### IV. CONCLUSION

There are two main parameters, the extinction coefficient and absorption coefficient, which can distinguish different types of char. The refractive index was found to be similar in all samples and is not able to be used to distinguish char type.

Future measurements involve more precise measurements with various types of char and over a larger frequency range. The same packing factor will be used for consistency.

#### ACKNOWLEDGEMENTS

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