Bio-oil Characterization via UV-Vis Spectroscopy: Phenols and Aromatic Content

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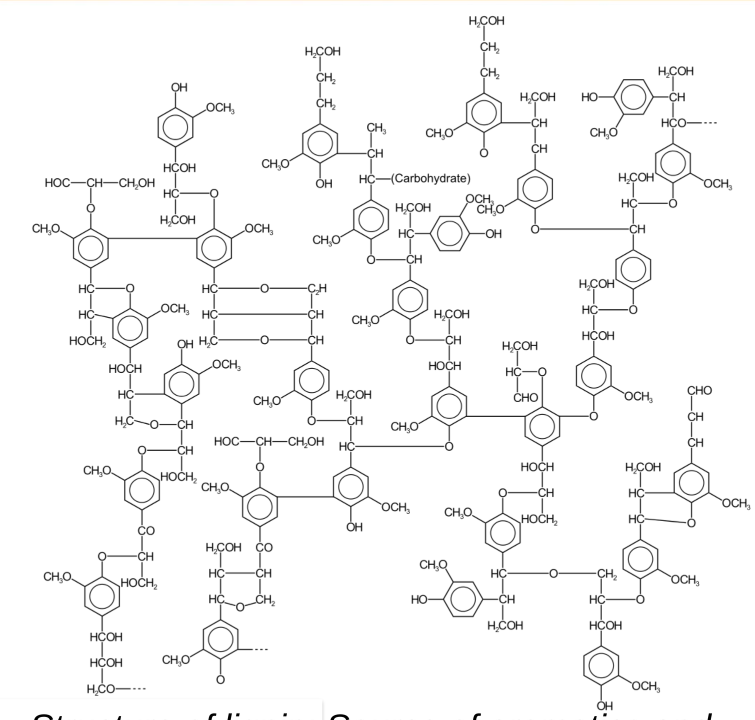
Introduction

- Biomass is an renewable alternative source of chemicals and fuels
- Pyrolysis: thermochemical process of converting solid biomass to liquid "bio-oil"
- Bio-oil is a complex mixture of fragmented products from carbohydrates and lignin
- Understanding components of bio-oil is important for final applications

Alamy (2014) Wine picture. Retrieved from http://www.telegraph.co.uk/foodanddrink/11266132/Drinking-a-glass-of-wine-is-the-same-as-downing-three-shots-of-vodka.html



Structure of lignin: Source of aromatics and phenolics in bio-oil

Glazer, A. W., and Nikaido, H. (1995). Microbial Biotechnology: fundamentals of applied microbiology. San Francisco: W. H. Freeman, p. 340.

Research Question

Can we use UV-Vis to quantify components in bio-oil?

Beer-Lambert Law:

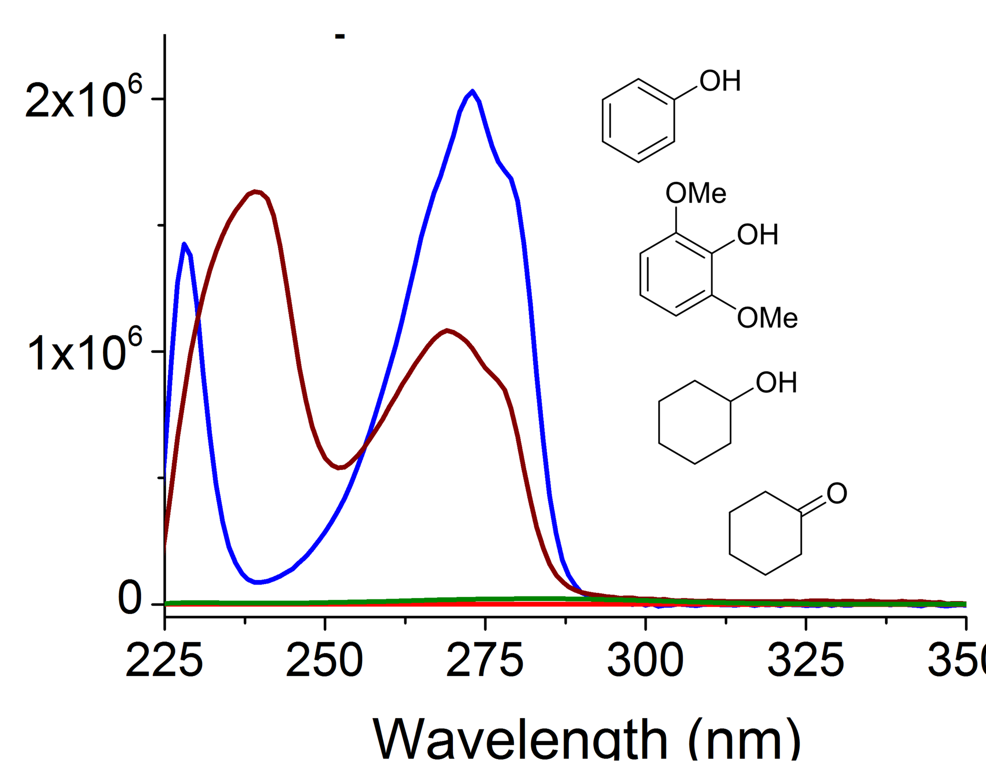
A=εlc

A =Absorption
ε = Molar Absorptivity (L $mol^{-1}cm^{-1}$)
l = Path Length (cm) *Length of the sample cell*
c = Concentration of the analyte in solution (mol L^{-1})

Aromatic Content

Background:

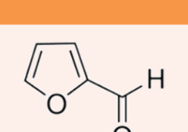
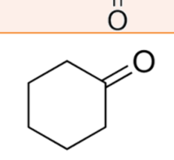
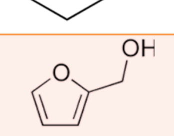
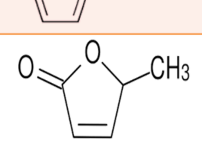
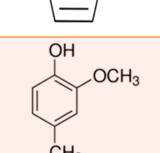
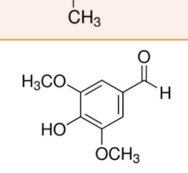
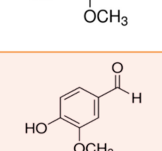
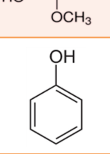
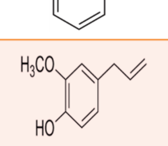
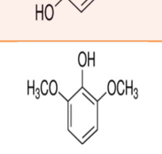
- Purpose: create a method using UV-Vis to analyze the aromatic components in bio-oil.
  - Specifically, to be able to quantify specific aromatic molecules in bio-oil.
- Lignin, which is one source of bio-oil, contains many aromatic rings. Once the material undergoes fast pyrolysis, bonds are broken between aromatic groups, which results in the many different aromatic molecules found in bio-oil. These molecules absorb at specific wavelengths, and therefore can be analyzed by UV-Vis.



Methods:

- A standard curve was made for each molecule.
- Molar absorptivity was calculated from the curves.

Results:

Molecule	Picture	Molar Absorptivity	Negative or positive?
Furfural		141032	P
Cyclohexanone		18.79340	N
Furfural Alcohol		68	P
Angelica lactone		9.61391	N
4-methyl guaiacol		1.0749	P
Syringaldehyde		119142	P
Vanillin		358452	P
Phenol		178892	P
Eugenol		311758	P
2,6 dimethoxyphenol		86660	P

Discussion:

- Results of this study show that some of the molecules absorbed greater than other molecules. We have concerns that if we have a mixture of compounds in bio-oil we would not be able to see the spectra of every component.
- It is speculated that separation methods may be necessary to properly analyze all components.

Phenolic Content

Background:

- Purpose: develop and test methods for quantifying components of bio-oil, specifically phenols using the Folin–Ciocalteu (FC) reagent.
- The FC method is used in the wine industry to quantify the phenolic content.
- Bio-oil contains many phenolics.
- This work was originally performed by Rover and Brown (2013).
- Our group sought to test the method for applicability to bio-oil.
- Phenolics are considered problematic compounds in the conversion stage.
- They can react with other compounds to form polymers that can plug a reactor, leading to expensive repairs and wasted time.

Methods:

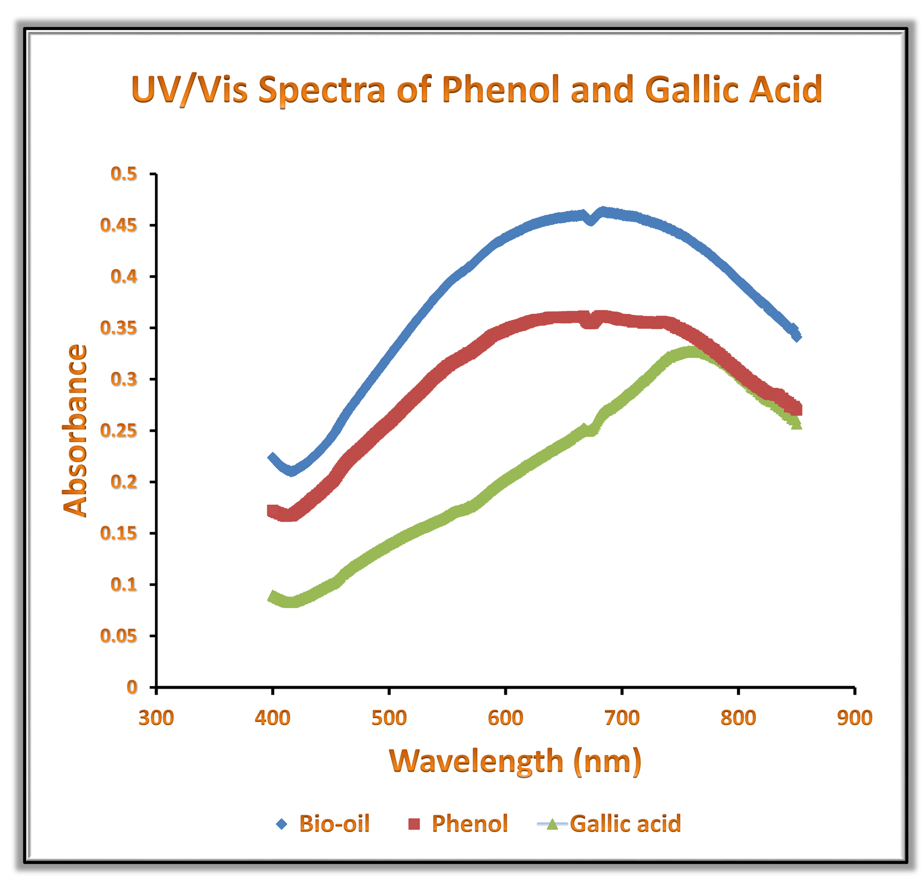
- The method is from Rover and Brown (2013).
- The FC method was used on a known quantity of phenol and gallic acid.
- Both a standard curve for phenol in 1:1 DCM and Methanol was developed and for Gallic acid in water.
- Liquid-liquid extraction method was also tested for applicability towards our work.
- The product of this extraction method was tested with the FC method.

Results:

- We constructed a calibration curve for Gallic acid as suggested by the literature.
- The graph shows the spectra for bio-oil, phenol, and gallic acid. The absorbance maximum for gallic acid is not the same as the bio-oil or phenol.
- Phenol may be a better standard, but appears to have limited solubility in water.

Discussion:

- Liquid-liquid extraction of phenolics in bio-oil is a viable method.
- Further work needs to be done on the yield from liquid-liquid extraction.
- UV-Vis characterization of the extract needs further work.
- A better standard than gallic acid needs to be investigated.
- Solvents for phenol needs to be further investigated.



Conclusion:

- UV-Vis can be used for analyzing bio-oil.
- Further testing of the FC method is required.
- The components investigated can be analyzed by UV-Vis within some limitations.
- Phenol solubility needs to be addressed for FC method.

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Rover, M. R., & Brown, R. C. (2013). Quantification of total phenols in bio-oil using the Folin–Ciocalteu method. *Journal of Analytical and Applied Pyrolysis*, *104*, 366–371. doi: 10.1016/j.jaap.2013.06.011