**Supplementary Material**

# Influence of the Carbonization Process on Activated Carbon Properties from Lignin and Lignin-Rich Biomasses

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## Contents

**Table S1 - Fiber analysis of the beech wood, pine bark and oak bark**

| | Beech wood [a] | Pine bark [b] | Oak bark [c] |
|---|---|---|---|
| **Lignin (ADL) %** | 14.7 | 44.9 | 19.6 |
| **Cellulose (ADF - ADL) %** | 57.8 | 25.4 | 30.0 |
| **Hemicellulose (NDF - ADF) %** | 19.4 | 14.7 | 20.5 |

a) measured and calculated based on the method proposed by van Soest et al. [1]

b) from [2]

c) from [3]

**Table S2 - Maximal pressures after hydrothermal carbonization reactions**

| | Pressure after reaction time (bar) | | |
|---|---|---|---|
| | **Repetition 1** | **Repetition 2** | **Repetition 3** |
| Indulin | 28 | 28 | - |
| Kraft Lignin | 28 | 28 | 27 |
| Organosolv Lignin | 40 | 43 | - |
| Low Sulfonate Lignin | 30 | 31 | 27 |
| Pine wood bark | 39 | 39 | 37 |
| Oak wood bark | 48 | 51 | - |
| Beech wood | 44 | 46 | 45 |

**Table S3 – Organic composition of the HTC process waters measured with GC-FID.**

| Precursor | Content ($mg/g_{Dry\ Matter}$)* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Phenol | Guaiacol | Catechol | 4-Methyl-guaiacol | 4-Ethyl-guaiacol | Syringol | Vanillin | Furfural |
| Beech wood | N.D. | <0.2 | <1.3 | N.D. | N.D. | 0.53 | <0.25 | 0.82 |
| Oak bark | N.D. | 0.50 | <1.3 | 0.51 | N.D. | 0.27 | N.D. | N.D. |
| Pine bark | N.D. | <0.2 | <1.3 | N.D. | N.D. | N.D. | N.D. | N.D. |
| Low sulfonate lignin | N.D. | 1.96 | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| Alkali kraft lignin | <0.2 | 2.97 | <1.3 | 0.23 | 0.33 | <0.25 | 0.44 | N.D. |
| Indulin AT lignin | <0.2 | 2.27 | <1.3 | <0.2 | 0.25 | <0.25 | 0.54 | N.D. |

*Calculated from measured concentrations. N.D.: not detected.

The process water from Organosolv lignin was not analyzed since the extraction process of the organic components was not possible. This was attributed to an unclear boundary between the organic and the aqueous phase after the separation process. For this reason, a quantitative measurement could not be done. Instead, a qualitative analysis was conducted using a different column and it was possible to determine that the ratio of phenol to guaiacol was 1:1.

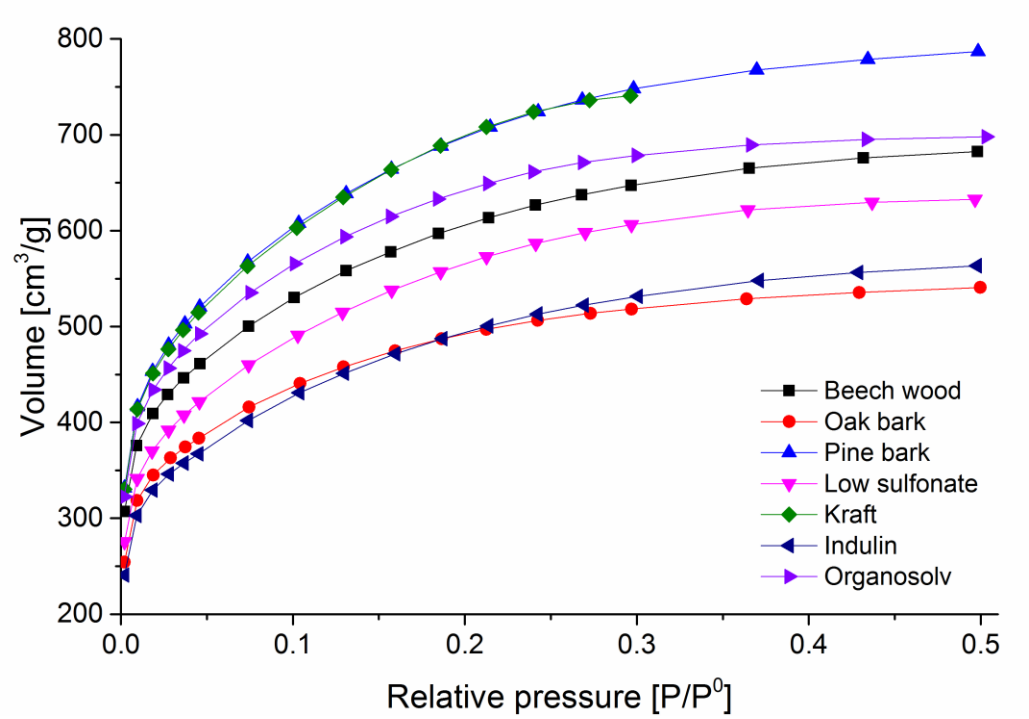
**Table S4 – Minerals found in the HTC process water measured with ICP-OES.**

| Precursor | Content ($mg/g_{Dry\ Matter}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ca | K | Mg | Mn | Na | P | S | Si | Zn |
| Beech wood | 1.23 | 1.18 | 1.52 | 0.14 | 0.09 | 0.081 | 0.07 | 0.05 | 0.002 |
| Oak bark | 8.65 | 1.39 | 2.55 | 0.07 | 0.23 | <0.02 | 0.35 | 0.44 | 0.003 |
| Pine bark | 1.55 | 0.49 | 0.69 | 0.01 | 0.15 | 0.067 | 0.14 | 0.17 | 0.009 |
| Low sulfonate lignin | 0.02 | 0.67 | 0.29 | 0.005 | 30.9 | <0.02 | 18.4 | 0.06 | 0.001 |
| Alkali Kraft lignin | 0.06 | 0.86 | 0.25 | 0.003 | 5.68 | <0.02 | 5.84 | 0.16 | 0.000 |
| Indulin AT lignin | 0.10 | 0.71 | 0.33 | 0.007 | 5.59 | <0.02 | 5.21 | 0.13 | 0.001 |
| Organosolv lignin | 0.09 | 0.30 | 0.08 | 0.001 | 2.57 | 0.087 | 0.51 | 0.26 | 0.001 |

*Calculated from measured concentrations

**Fig. S1 - $N_2$ Isotherms**

$N_2$ Isotherms – Hydrochars




$N_2$ Isotherms – Pyrochars

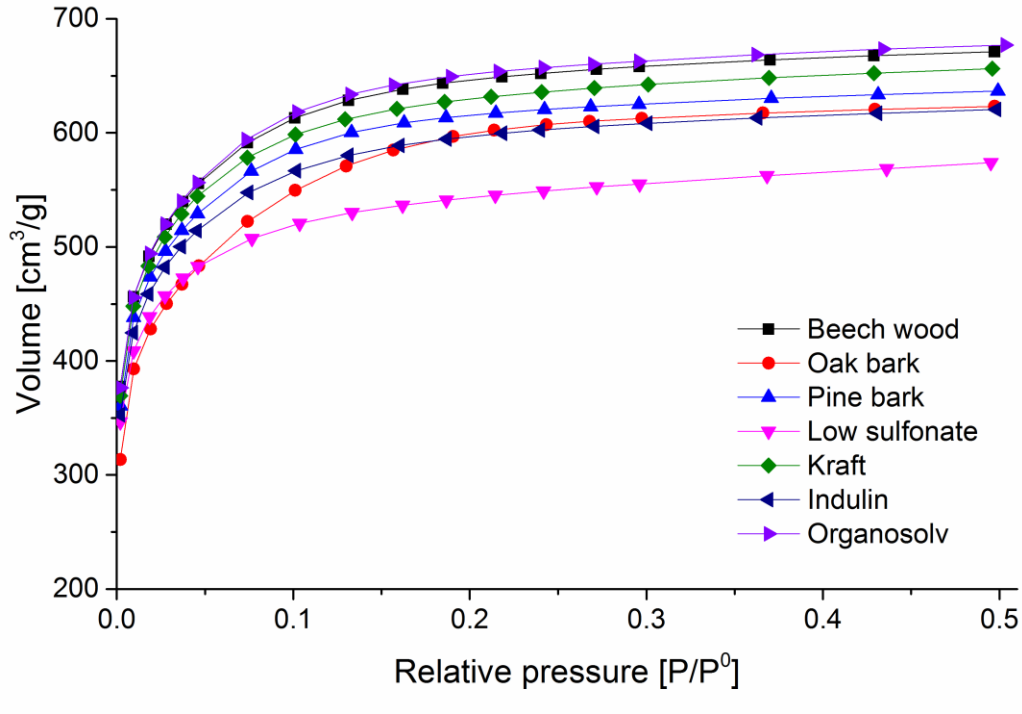
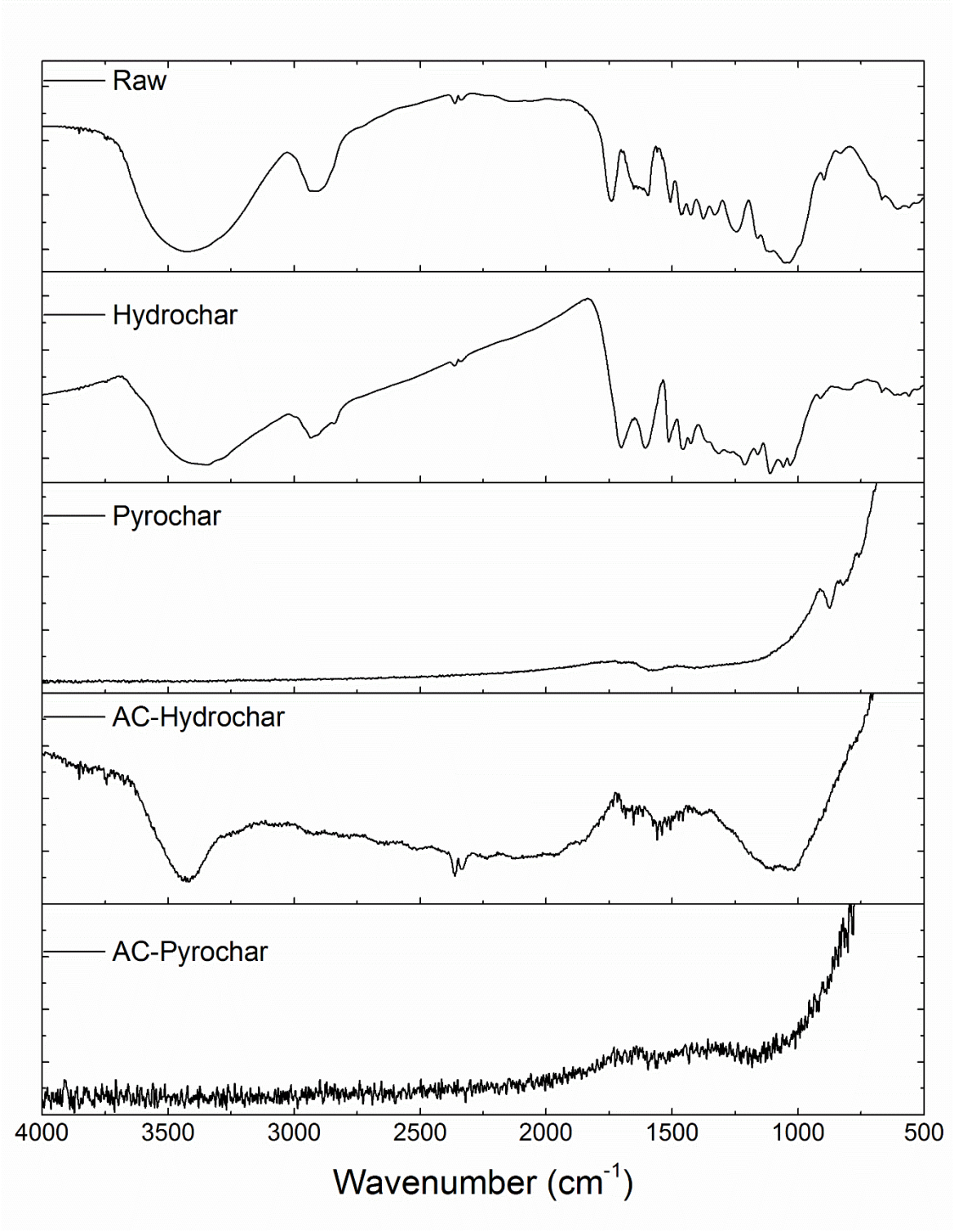
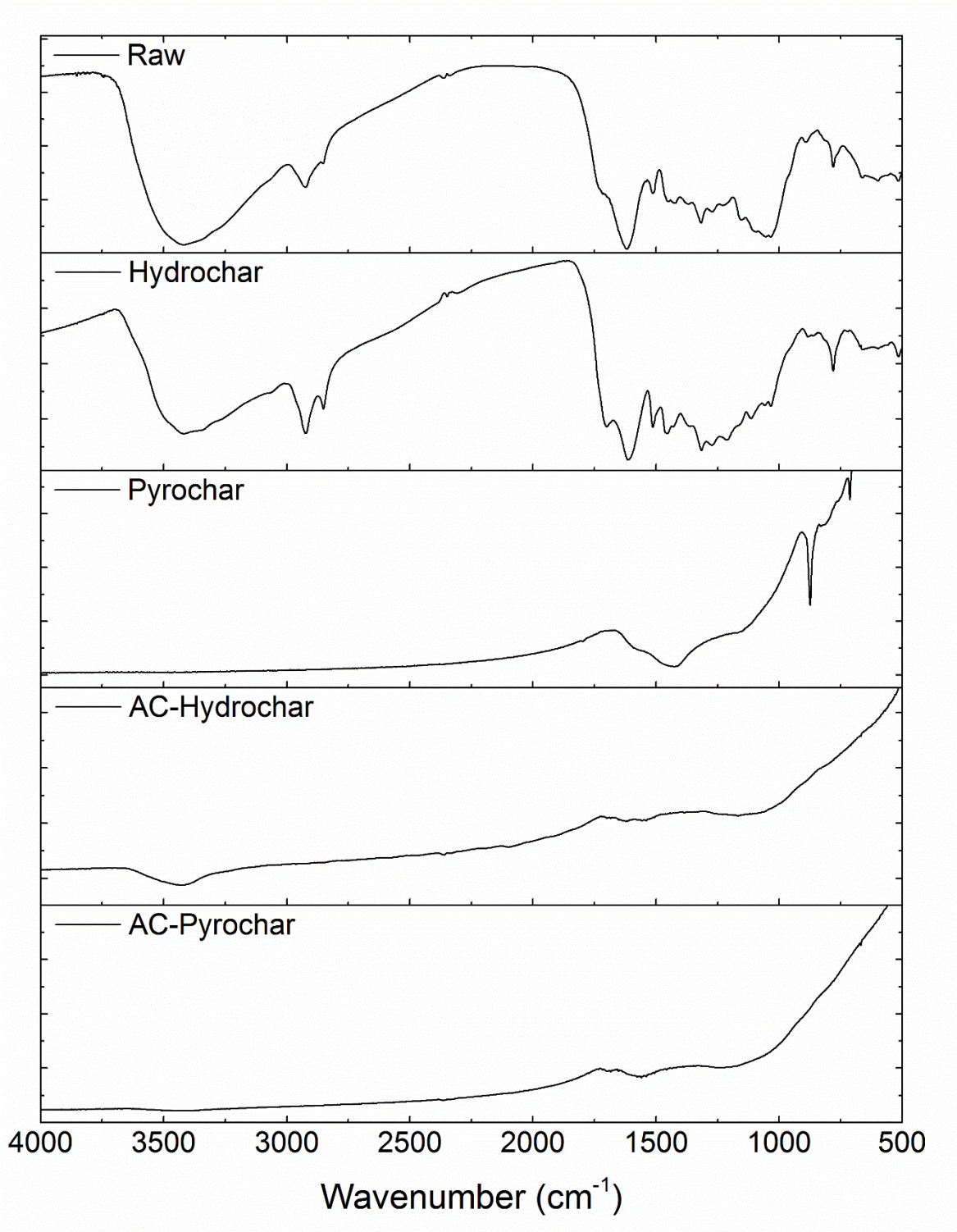


**Fig. S2 - FTIR Spectra - Beech Wood**



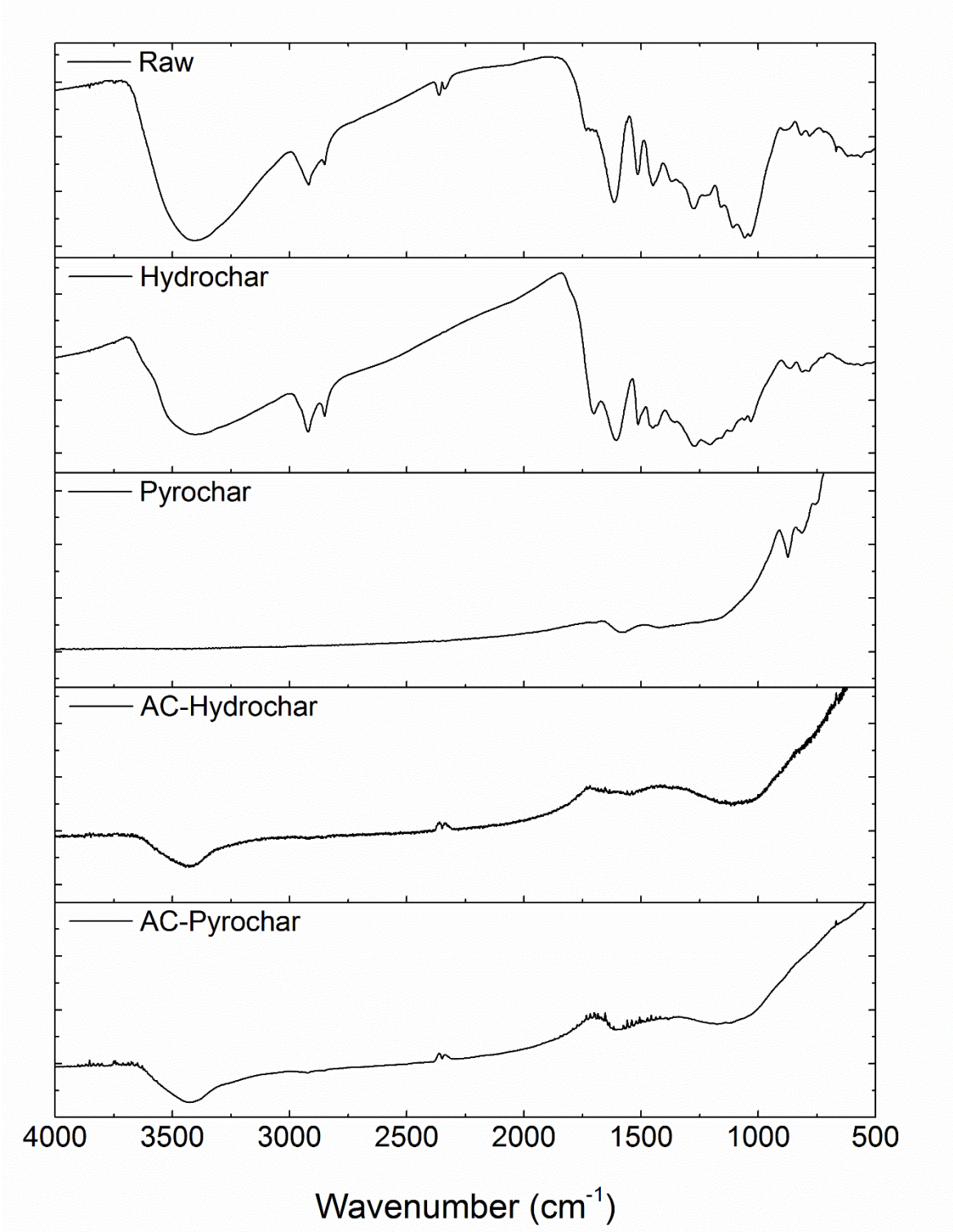

Y-axis scaling and units are arbitrary

**Fig. S3 - FTIR Spectra - Oak Bark**



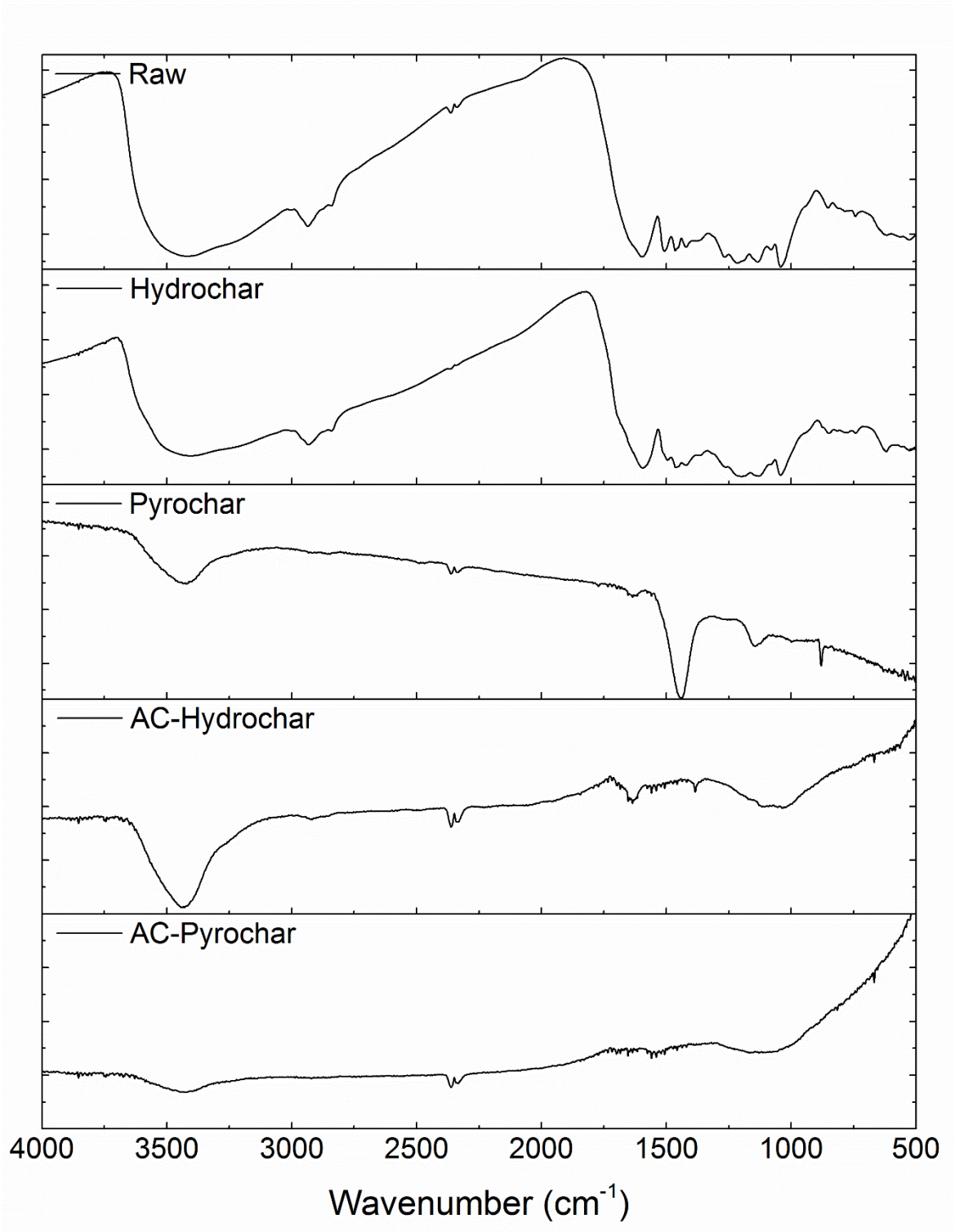

Y-axis scaling and units are arbitrary

**Fig. S4 - FTIR Spectra - Pine Bark**



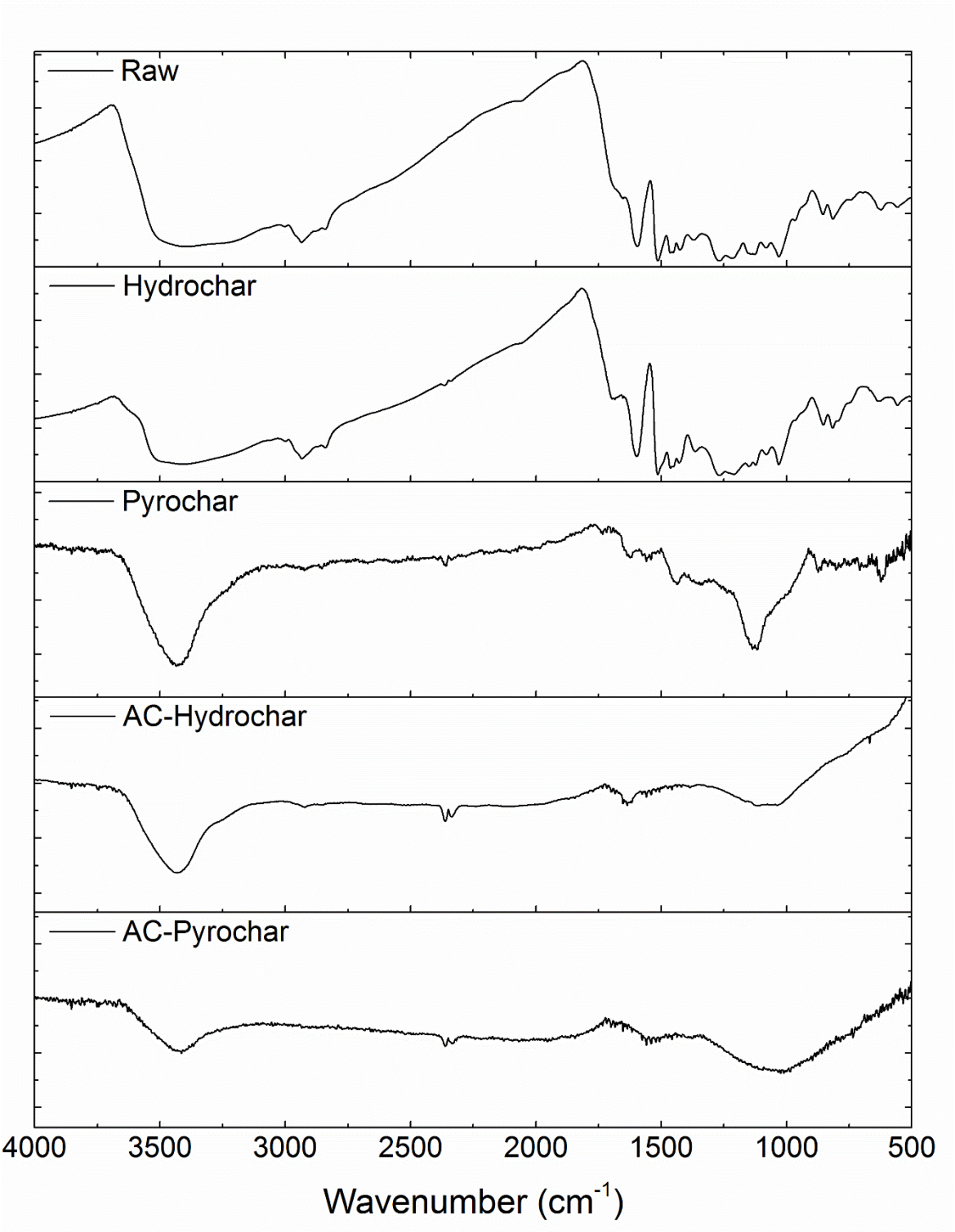

Y-axis scaling and units are arbitrary

**Fig. S5 - FTIR Spectra - Low Sulfonate Lignin**



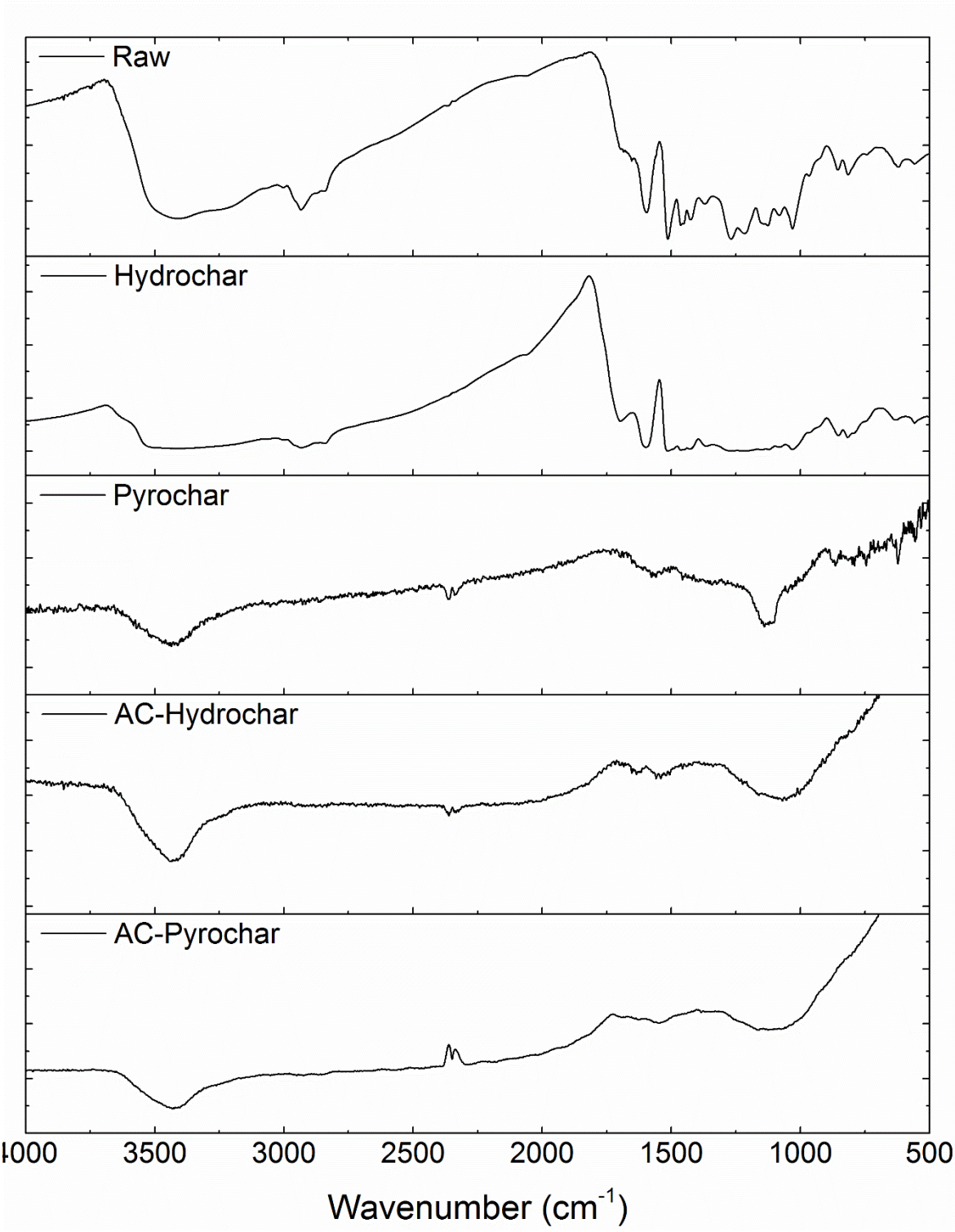

Y-axis scaling and units are arbitrary

**Fig. S6 - FTIR Spectra - Alkali Kraft Lignin**



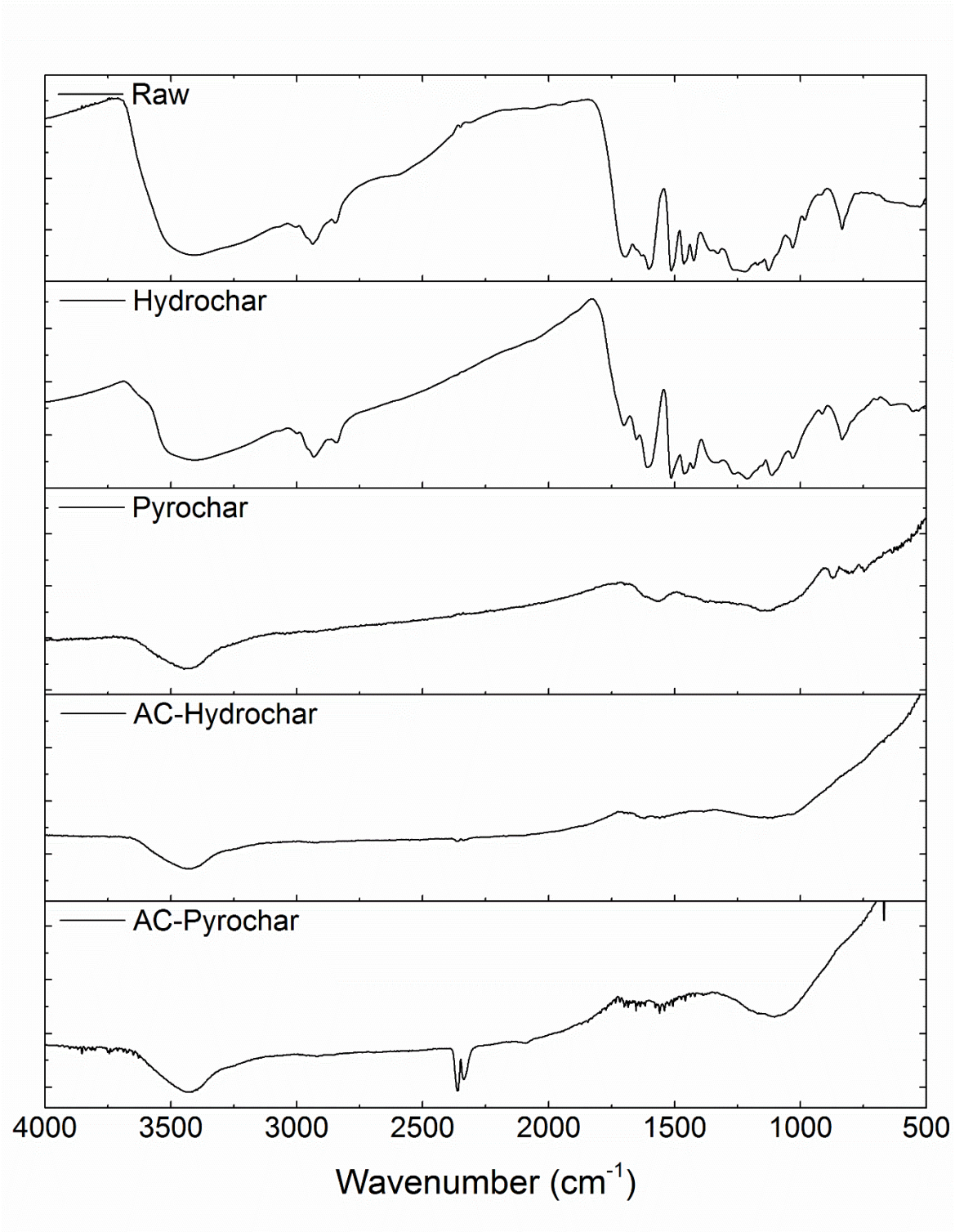

Y-axis scaling and units are arbitrary

**Fig. S7 - FTIR Spectra - Indulin AT Lignin**



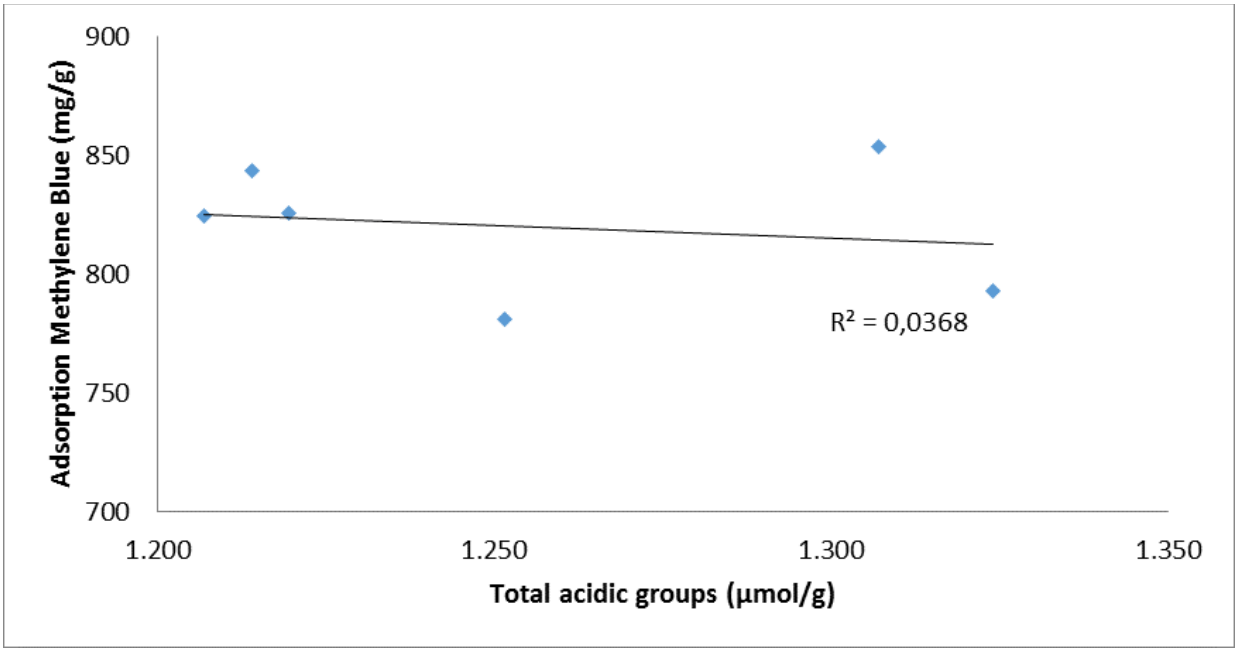

Y-axis scaling and units are arbitrary

**Fig. S8 - FTIR Spectra - Organosolv Lignin**




Y-axis scaling and units are arbitrary

**Fig. S9 - Methylene blue adsorption vs. total acidic groups**



1. **Fig. S10 - GC-FID Spectrum - Beech Wood HTC Process Waters**

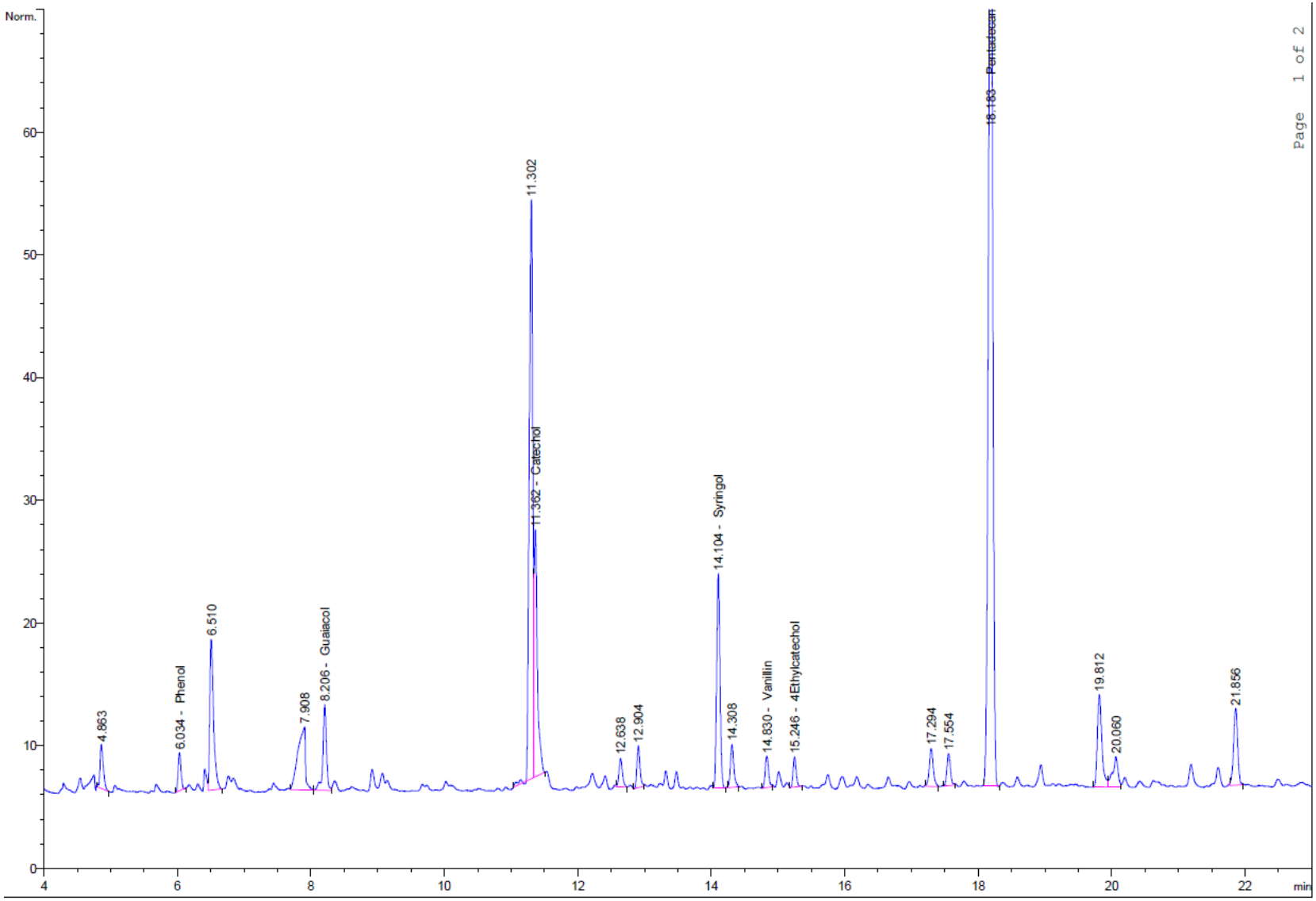


**Fig. S11 - GC-FID Spectrum - Oak Bark HTC Process Waters**

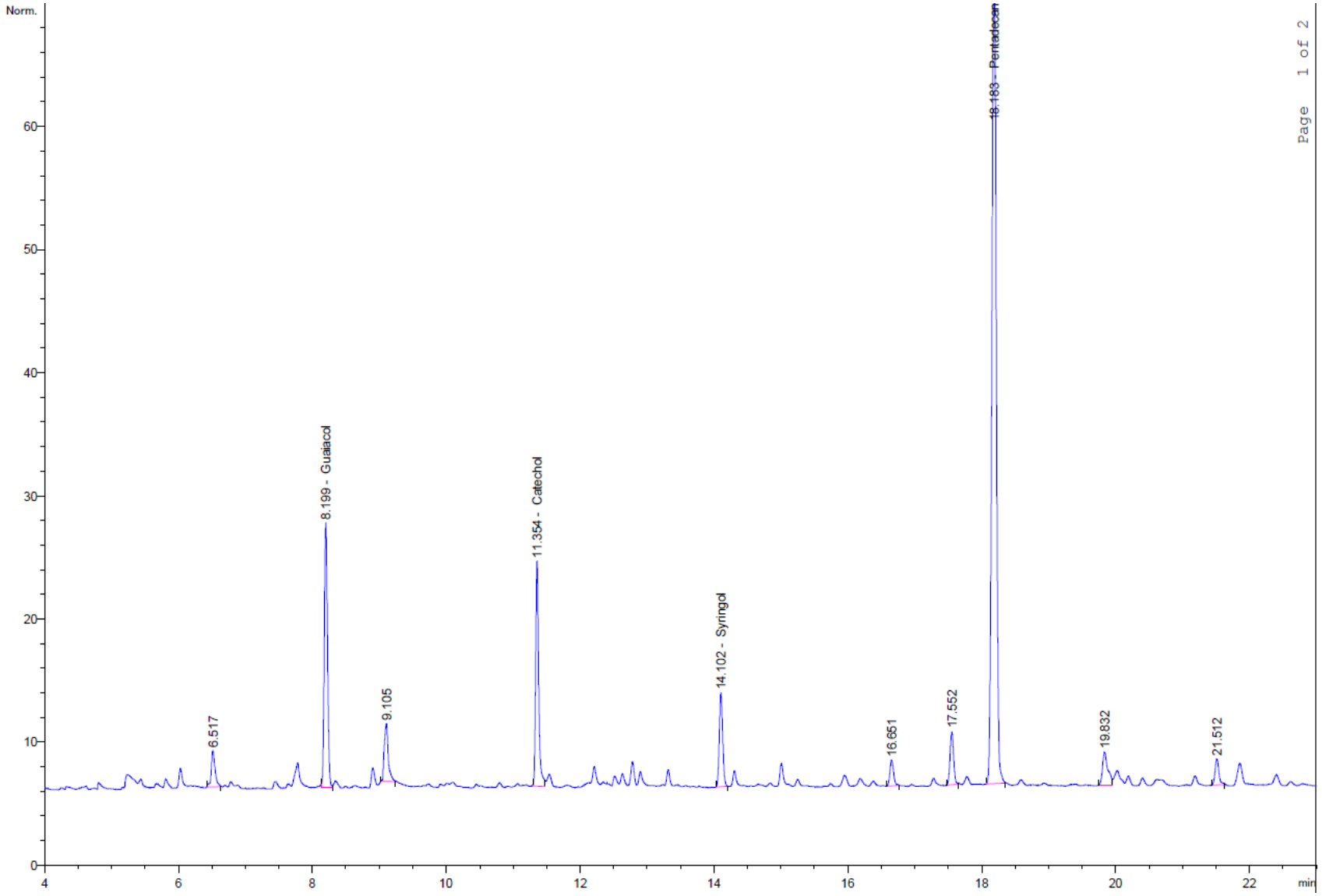


**Fig. S12 - GC-FID Spectrum - Pine Bark HTC Process Waters**

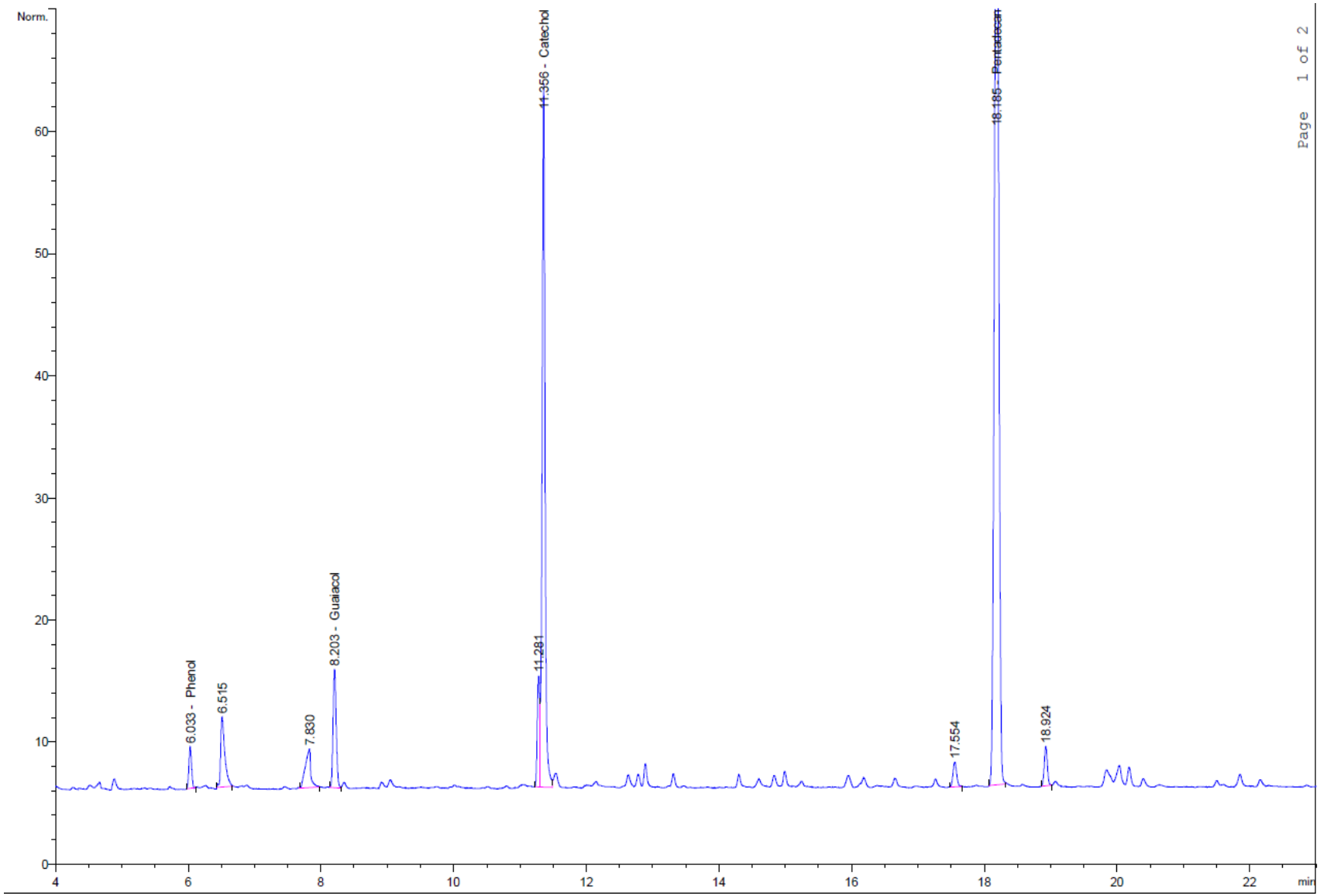


**Fig. S13 - GC-FID Spectrum - Low Sulfonate Lignin HTC Process Waters**[5]

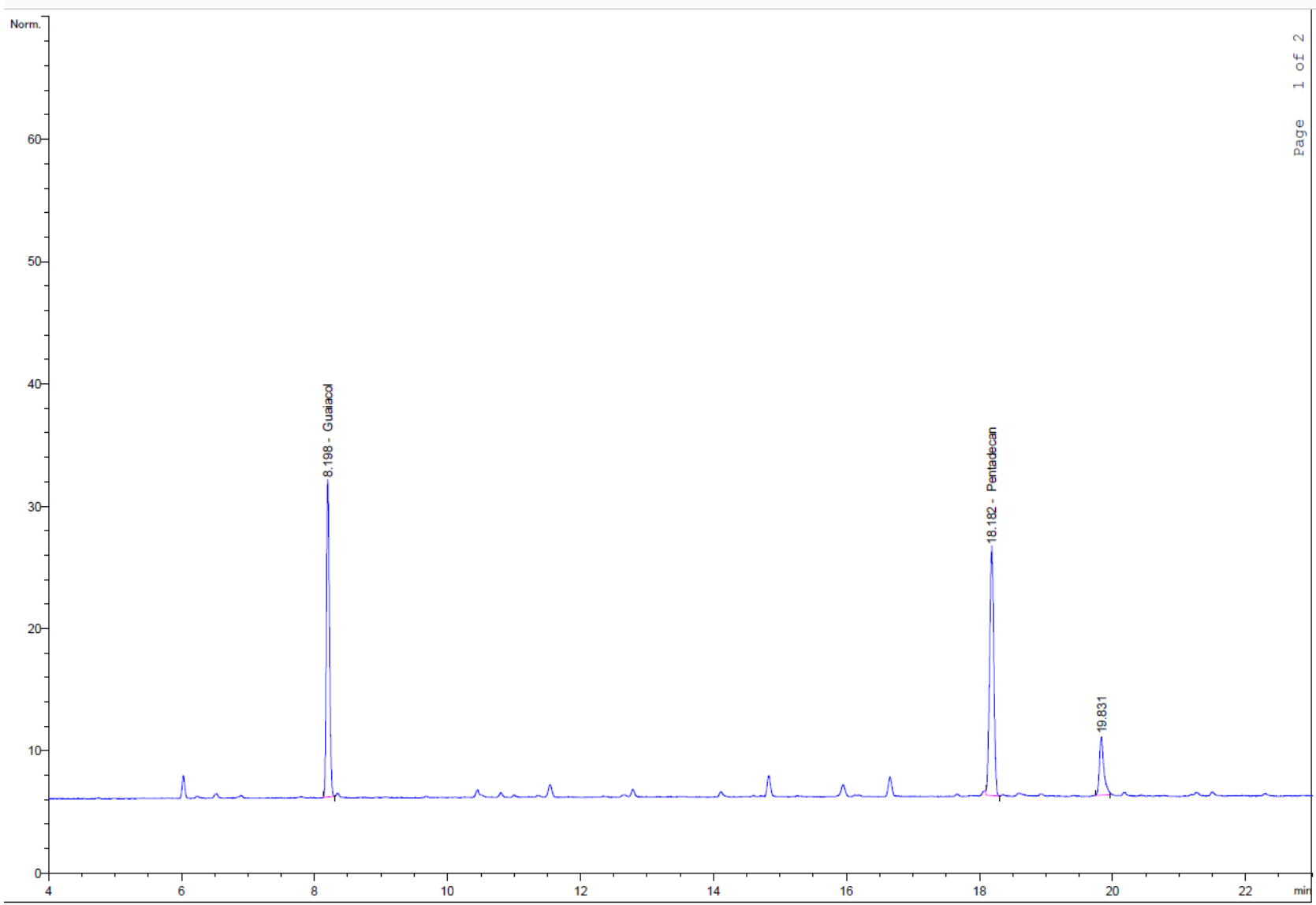


**Fig. S14 - GC-FID Spectrum - Alkali Kraft Lignin HTC Process Waters**

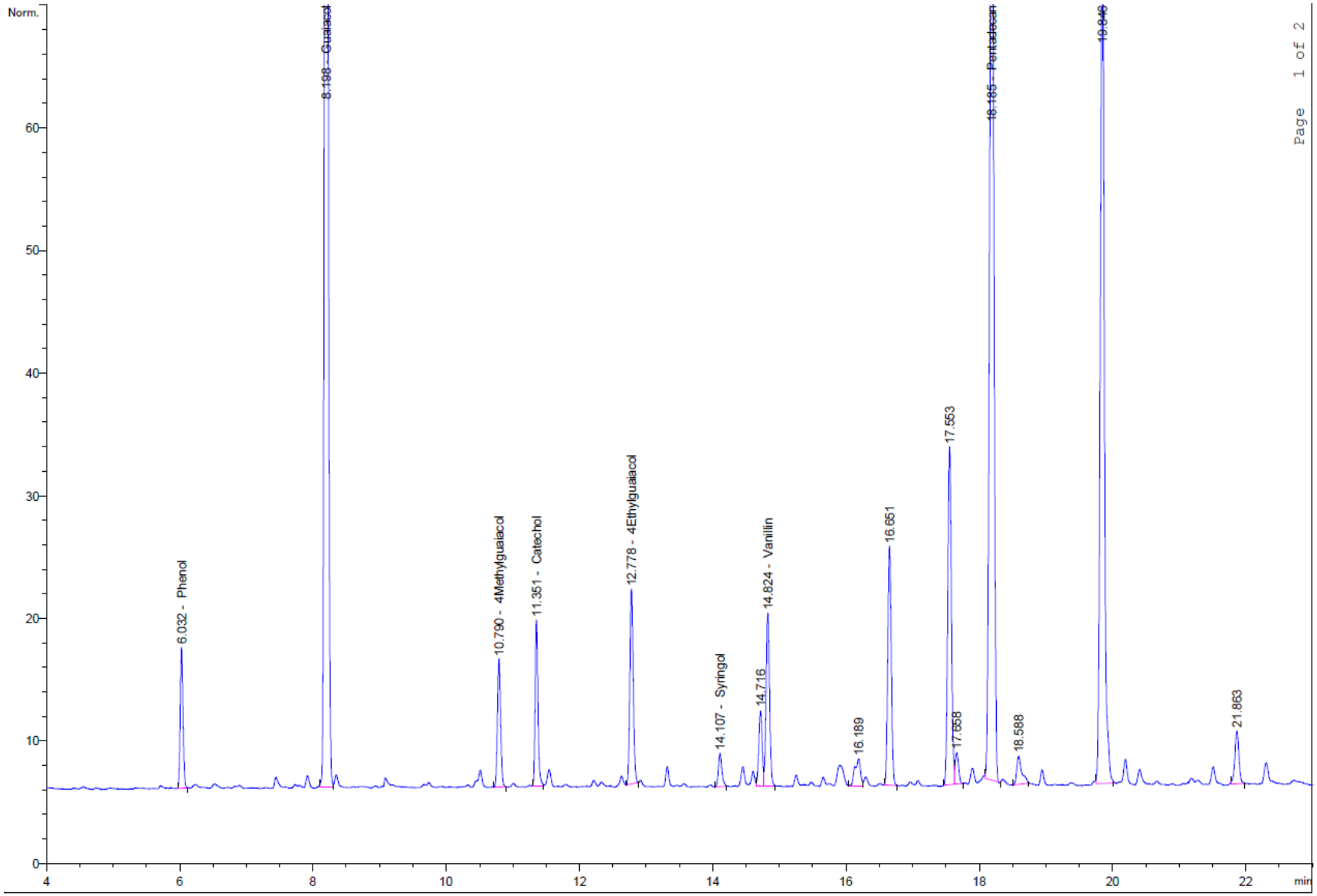
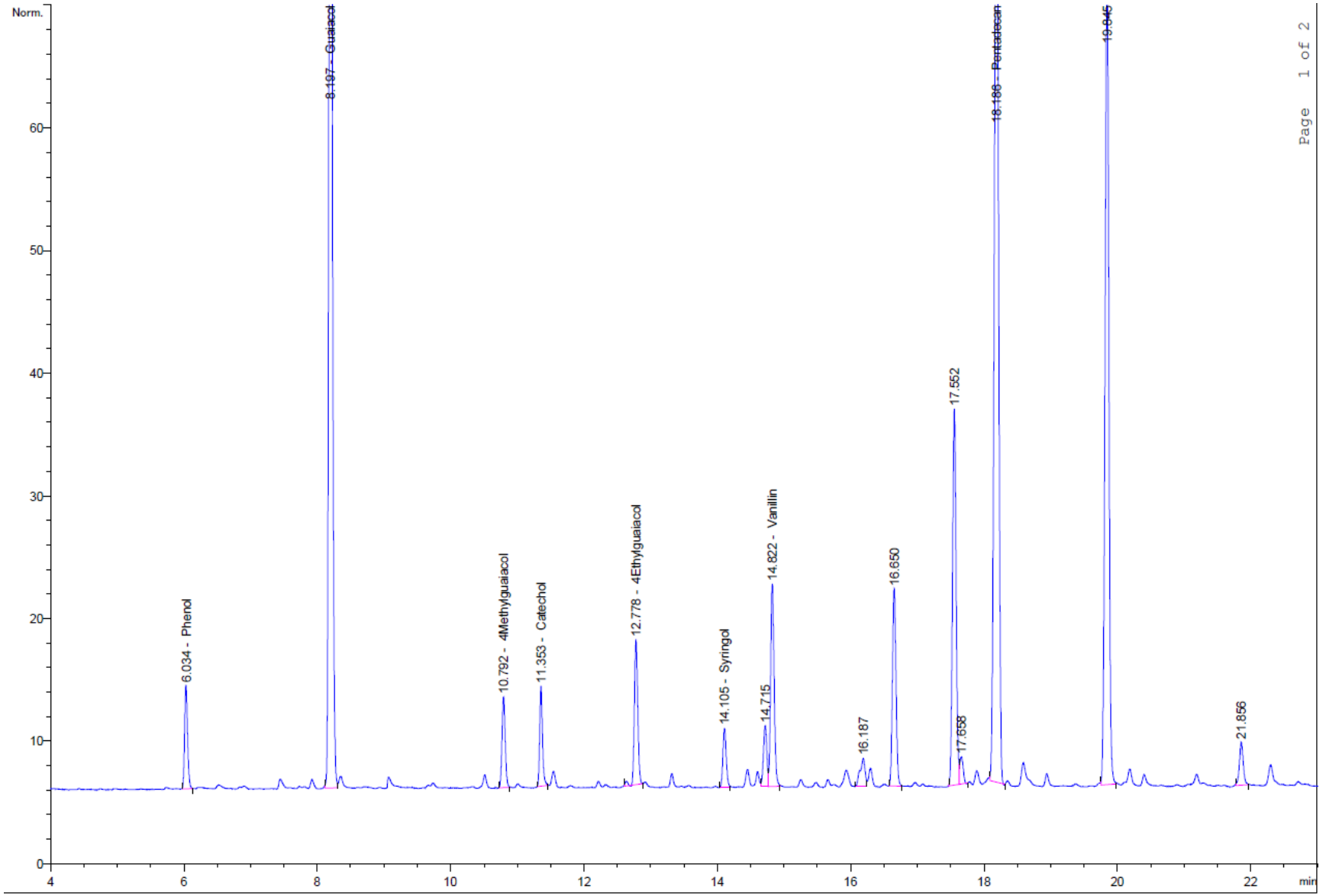


**Fig. S15 - GC-FID Spectrum - Indulin AT Lignin HTC Process Waters**



**References Supplementary Material**

[1] P.J. Van Soest, J.B. Robertson, B.A. Lewis, Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition, J. Dairy Sci. 74 (1991) 3583–3597. doi:10.3168/jds.S0022-0302(91)78551-2.

[2] L. Valentín, B. Kluczek-Turpeinen, S. Willför, J. Hemming, A. Hatakka, K. Steffen, et al., Scots pine (Pinus sylvestris) bark composition and degradation by fungi: Potential substrate for bioremediation, Bioresour. Technol. 101 (2010) 2203–2209. doi:10.1016/j.biortech.2009.11.052.

[3] W. Jin, K. Singh, J. Zondlo, Pyrolysis Kinetics of Physical Components of Wood and Wood-Polymers Using Isoconversion Method, Agriculture. 3 (2013) 12–32. doi:10.3390/agriculture3010012.