On the development of phenol-formaldehyde resins using a new type of lignin extracted from pine wood with a levulinic-acid based solvent

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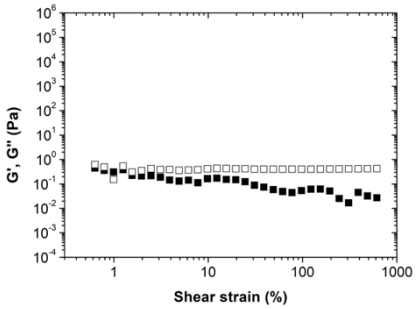
Supplementary information

Without lignin



30 % Lignin

50 % Lignin

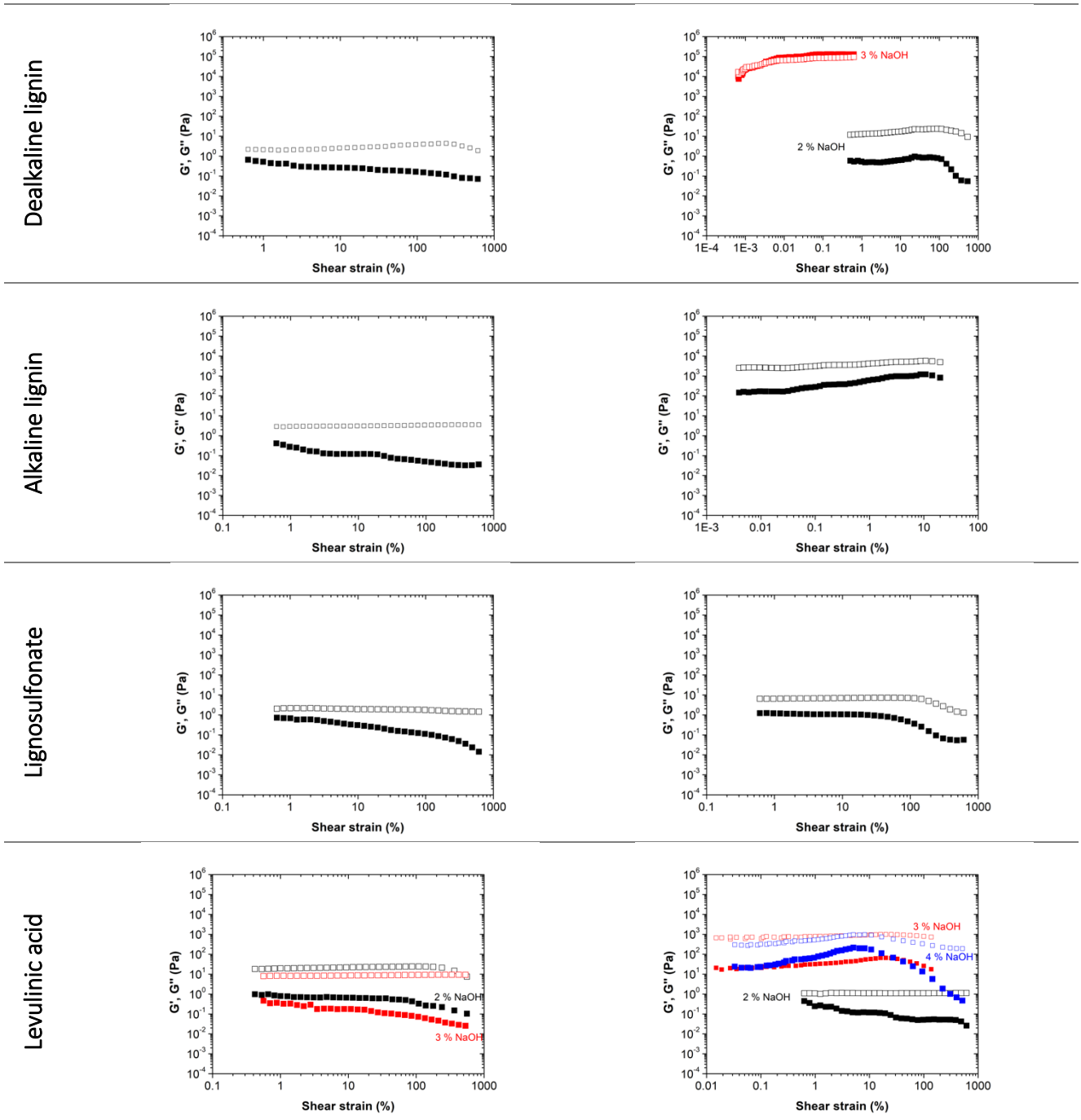


Figure S1. Strain amplitude sweep of resole resins, at 1 Hz and 20 °C. G′ is representing by full squares, while G′′ by empty squares. The different colors indicate the different NaOH concentration: 2 % - black, 3 % - red, 4 % - blue.

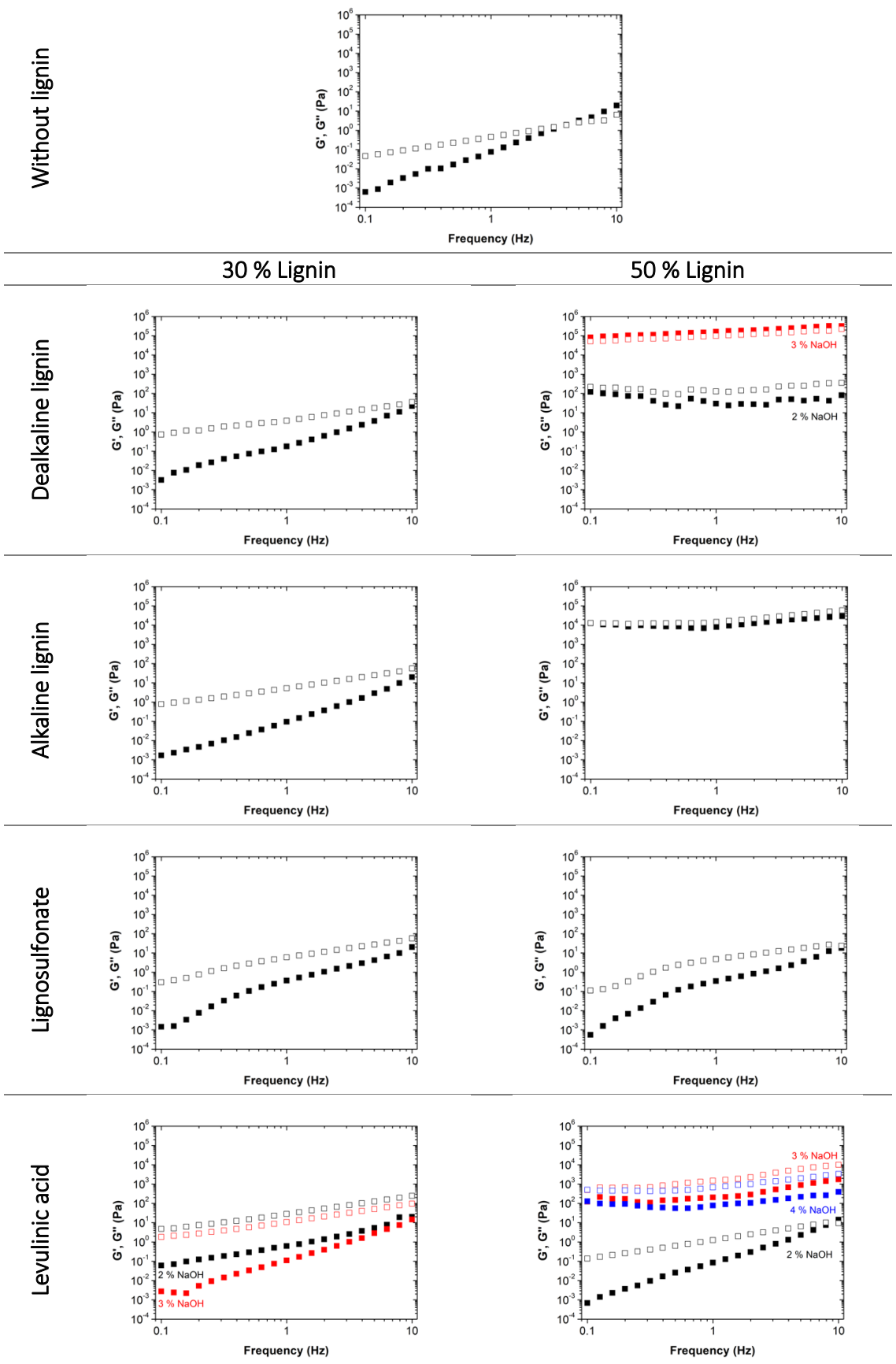


Figure S2. Frequency sweep of resole resins, at 5 Pa and 20 °C. G′ is representing by full squares, while G′′ by empty squares. The different colors indicate the different NaOH concentration: 2 % - black, 3 % - red, 4 % - blue.

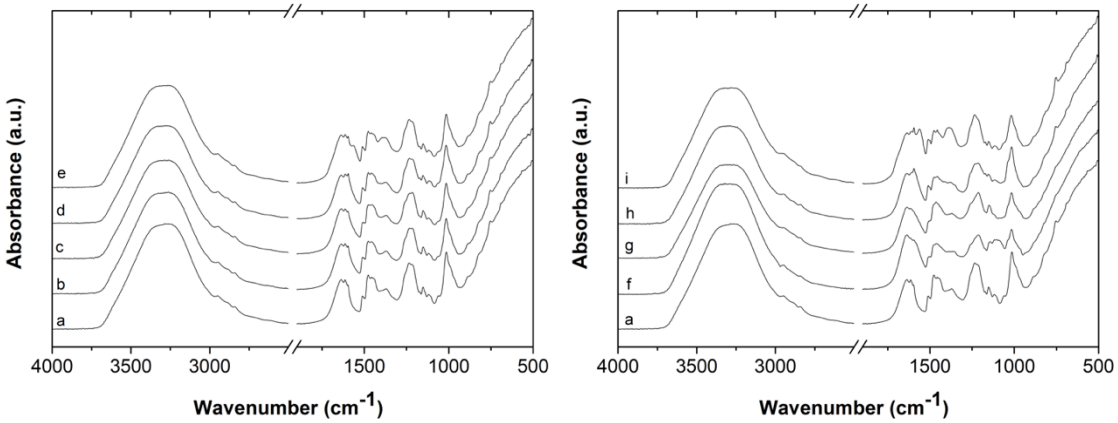


Figure S3. Normalized FTIR spectra of phenolic resins (a), 30 % (b-e) and 50 % (f-i) phenol replaced by lignin, using dealkaline lignin (b ,f), alkaline lignin (c, g), lignosulfonate (d, h) and lignin recovered from pine wood with levulinic acid (e, i), for optimized reins.