Tension Wood Provides Insight Into Structural Changes in Biomass Resulting from Chemical Pretreatment

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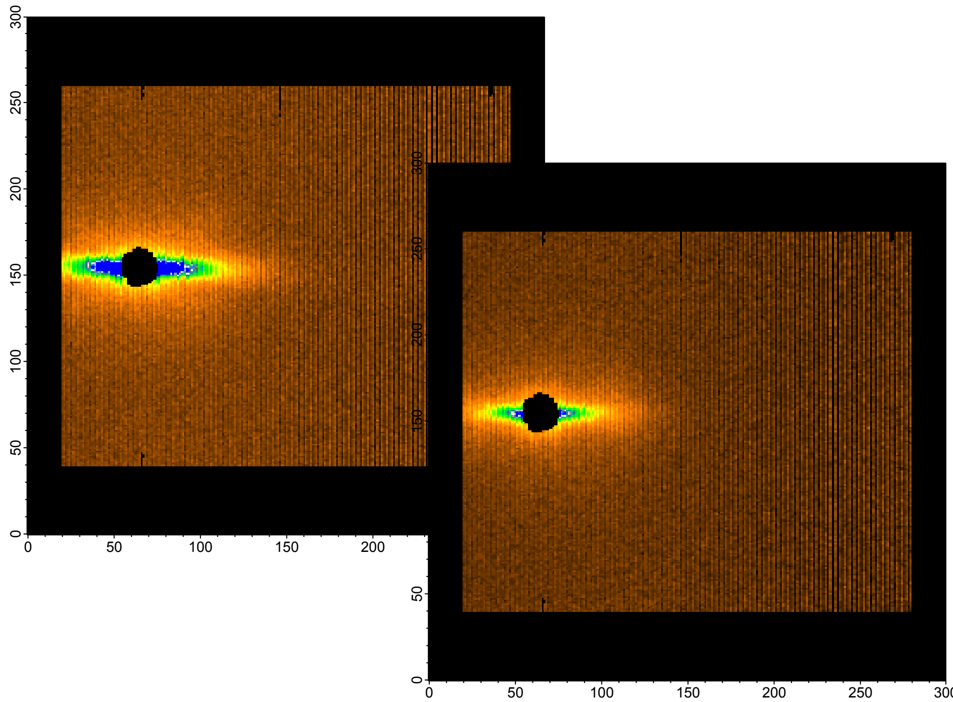
http://cmb.ornl.gov/research/bioenergy/lignocellulose-dynamics

Project Goals: Lignocellulosic biomass comprises the vast majority of biomass on Earth and has the potential to play a major role in generation of renewable biofuels if cost-effective conversion can be achieved. Largely composed of plant cell walls, it is a complex biological composite material that is recalcitrant to the structural deconstruction and enzymatic hydrolysis into sugars that is necessary for fermentation to bioethanol. The Scientific Focus Area in Biofuels is developing "Dynamic Visualization of Lignocellulose Degradation by Integration of Neutron Scattering Imaging and Computer Simulation" for multiple-length scale, real-time imaging of biomass during pretreatment and enzymatic hydrolysis. This is providing fundamental information about the structure and deconstruction of plant cell walls that is needed to drive improvements in the conversion of renewable lignocellulosic biomass to biofuels.

Plant cell walls comprise the bulk of lignocellulosic biomass. Therefore, a greater understanding of the chemistry, architecture, physical and mechanical properties of cell walls is essential to improve biomass-based biofuel production. Here we propose to understand biomass properties underlying recalcitrance to enzyme-based sugar release. Towards this end, the spatio-temporal progression in chemical and anatomical changes that occur in growing plants under tension stress, called tension wood, were investigated. Hydrolysis of tension wood gives 3-fold increased glucose yield compared to normal wood.[1] Limited structural insights from previous work postulated that the absence of characteristic diffraction peaks stemmed from laterally aligned microfibrils.[2]

Therefore, we carried out structural studies of tension wood using small-angle neutron scattering performed at the Bio-SANS instrument.[3] Tension wood was produced from *Populus tremula x alba* grown subjected to tension stress and normal (or control) wood from a plant grown in identical conditions except for the application of the tension stress. Intact microtomed samples prepared from plants consisted of normal, opposite (to the tension-stressed site), and tension wood samples. The normal and tension wood samples resulted in an anisotropic scattering pattern with the latter sample showing enhanced anisotropy (see figure). Although opposite wood also showed evidence of anisotropy, it was much less pronounced than tension and normal wood samples (not in figure). Structural features observed for normal wood sample at the higher scattering angles were modeled as a long cylinder with a cross-section that represents the crystalline cellulose elementary fibril ($R_g = 10 \sim 11$ Å).[4] The same feature was evident in the tension wood sample, however, multiple sizes were required describe the data optimally. Size distribution analysis of the scattering curve showed evidence of association between elementary fibrils forming different sizes of aggregates. Most interestingly, when the sizes of all the aggregates were summarized, distinct multiples of the elementary fibrils were obtained such as twice and thrice the size of an average elementary fibril. This propensity of the cellulose microfibrils to associate due to the application of tension stress mimics plant nanostructural evolution as observed during most thermochemical pretreatments, especially dilute acid pretreatment.



SANS 2d image of tension (left) and normal (right) wood samples depicting the differing degree of anisotropy in the scattering profiles.

References

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3. The development of cell was partially funded by the Oak Ridge National Laboratory's Center for Structural Molecular Biology (CSMB), which is supported by the Office of Biological and Environmental Research, using facilities supported by the U.S. Department of Energy, managed by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.
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