# Nanoscale Architecture of Plant Cell Walls Determines Their Accessibility and Digestibility by Enzymes

U.S. DEPARTMENT OF ENERGY | Office of Science

## Background:

Plant cell walls are complex nanocomposites containing networks of cellulose fibrils and complex “matrixing” polymers. There is little agreement about which plant cell wall features most affect digestibility by microbes and cellulolytic enzymes. The overall performance of biomass saccharification may be attributed to the synergistic action of many complementary enzymes, which makes it difficult to study one factor at a time. Traditional solution methods have suffered from the classical ensemble average limitation presented by analysis of these mixtures of complex biomass, and the bulk data measurements gathered are therefore sometimes inconclusive and in part contradictory.

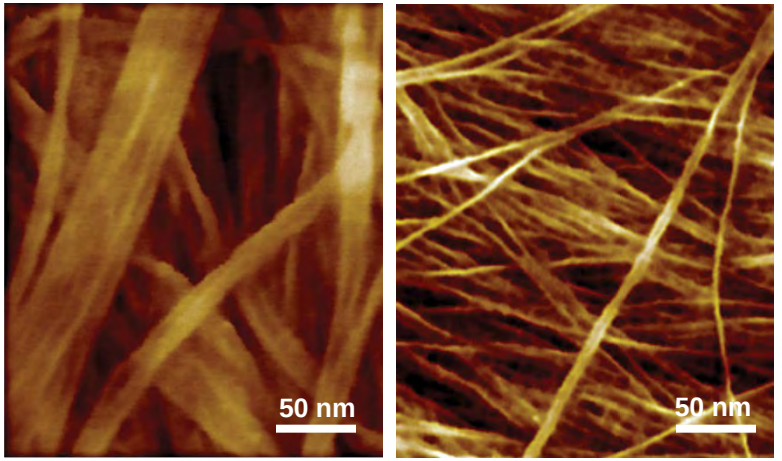
## Approach:

BESC researchers at National Renewable Energy Laboratory developed a suite of microscopic techniques and conducted real-time in situ imaging of the action of two commercially-relevant enzyme systems (i.e., bacterial cellulosomes and fungal cellulases) on untreated and delignified plant cell walls under controlled digestion conditions at the cellular and molecular resolutions. The combination of imaging techniques allowed observation of samples across 10 nm to 10 um length-scales.

## Outcomes:

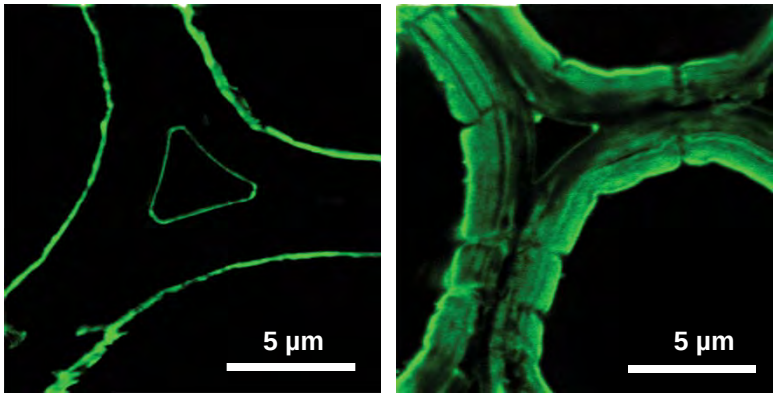
- High resolution imaging at real-time revealed different nanometer scale architecture of cell types, i.e., primary walls (PW) and secondary walls (SW), and suggest cellulase digests cell wall cellulose from its hydrophobic surfaces.
- Lignin physically hinders the accessibility of polysaccharides in the cell wall to enzymes. After delignification, all cell walls are rapidly digestible.
- Real-time imaging of enzyme digestion reveals different mechanisms of different enzyme systems. Fungal enzymes penetrate into the cell wall, resulting fast digestibility, large complexed cellulosomes digest the cell wall from the surface.

Nanoscale structure of plant cell walls by atomic force microscopy




**Primary wall (PW)** **Secondary wall (SW)**

Enzyme accessibility by Confocal laser scanning microscopy




**Bacterial cellulosomes** **Fungal cellulases**

## Significance:

- Our imaging data support the hypothesis that ideal pretreatments should maximize lignin removal and minimize polysaccharide modification, thereby retaining the essentially native microfibrillar structure and improving accessibility.

Citation: Ding, *et al*., How Does Plant Cell Wall Nanoscale Architecture Correlate With Enzymatic Digestibility? *Science* 338:6110 (1055-1060) 2012. doi: 10.1126/science.1227491

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