RE-DEFINING RECALCITRANCE: A MULTI-SCALE, MULTI-FACTOR AND CONVERSION-SPECIFIC PROPERTY OF BIOMASS

Maureen McCann[1], Haibing Yang, Matheus Benatti, Bryan Penning, Peter Ciesielski, Jacob Hinkle, Anna Olek, Tania Shiga, Hui Wei, Nick Anderson, Melvin Tucker, Bryon Donohoe, Michael Himmel, Clint Chapple, Mahdi Abu-Omar, Nate Mosier, Wendy Peer, Angus Murphy, Nicholas Carpita
[1]Purdue University
Bindley Bioscience Center, Discovery Park,
1203 W State Street,
West Lafayette, IN 47906, USA
mmccann@purdue.edu

Recalcitrance of biomass to enzymatic hydrolysis for biofuel production is thought to be a property conferred by lignin or lignin–carbohydrate complexes. However, chemical catalytic and thermochemical conversion pathways, either alone or in combination with biochemical and fermentative pathways, now provide avenues to utilize lignin and to expand the product range to liquid hydrocarbon biofuels. Removing lignin first from intact woody biomass as a source of high-value chemicals enables a re-visioning of the cellulosic biorefinery concept in which lignin is a waste stream or co-fired to produce heat. Our data show that, regardless of conversion process, biomass structural complexity at molecular, nanoscale, and mesoscale levels impacts the yields and selectivities of desired reaction products from catalytic and pyrolytic transformations. Therefore, we have modified the composition and architecture of cell wall components to optimize post-conversion product yields without compromising pre-conversion biomass yields. Our strategies to deliver metal catalysts throughout the cell wall structure and create functionalized sites ready for catalytic transformations may dramatically increase the effective surface area for catalysis of cellulose and xylan. Genetic redesign of the lignin network simplifies its architecture to enable facile catalytic disassembly and conversion of aromatics. We offer a new definition of recalcitrance as the molecular, nanoscale, and macroscale features of biomass that disproportionately increase energy requirements in conversion processes, increase the cost and complexity of operations in the biorefinery, and/or reduce the recovery of biomass carbon into desired products.

Supported by C3Bio, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Basic Energy Sciences.