IB IN DEPTH—Special Section on Advances in Biomass Characterization Technology

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Overview: The Increasing Importance and Capabilities of Biomass Characterization

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A long-held, time-tested business adage is that you can't manage what you can't measure. The growing industries of biobased products and bioenergy both confirm and contradict this cliché. On the one hand, mankind has been growing and utilizing biomass for fuels, energy, and products for thousands of years. We have been using biomass as a source of fibers, fuels, and products at an industrial scale for more than 100 years. One can argue that the biobased industries, which preceded the petroleum-based industries, were displaced largely due to stable, low costs of petroleum-based feedstocks and now are returning due to multiple drivers including cost, improved technologies, national security, and environmental sustainability.

On the other hand, even though we have been growing and using biomass successfully without having a complete understanding of its properties in the last decade, the combination of improved biological manipulation techniques and improved characterization measurements have given us a deeper understanding of biomass. This understanding should lead to management of improved feedstocks, whether natural or genetically modified, which are targeted for better conversion.[1] We are already seeing these types of results with genetically modified plants that yield improved bioconversion efficiencies and with the impact that natural genetic variability of feedstock can have on its bioconversion.[2,3]

Biomass, or more narrowly lignocellulosic biomass, is a complex molecular assemblage of three major components: cellulose, hemicelluloses, and lignin. Minor components such as ash, proteins, and other polymers like pectin are also present within the primary and secondary plant cell walls. Release of the carbohydrates contained within the cellulose and hemicellulose is the primary target for improved bioconversion. The phenolics in the lignin remain a target for value-added bioproducts.[4,5] Enhanced characterization of the starting biomass feedstock and its impact on subsequent pretreatment and conversion processes will allow either the selection of more appropriate feedstocks or better optimization of the processes.

The term characterization describes the measurement of the chemistry, structure, and interactions of the biomass components. The scientific and industrial communities need both faster and broader screening techniques as well as molecular and imaging techniques capable of more deeply probing the biomass. The National Renewable Energy Laboratory (NREL) method for biomass characterization has been the recent gold standard for this field, even though it requires multiple grams of sample and days of skilled technical support.[6,7] One very exciting area to emerge more recently has been the development of several high-throughput screening techniques that reduce the sample requirements to multiple milligrams and allow for greater automation. Pretreatment and enzymatic digestion steps can now be performed in a 96-well plate format and automated.[3,8–10] Santoro et al. incorporated grinding into their automated sample preparation protocol to improve digestibility for screening under multiple conditions.[11] These methods allow for screening of thousands of variant biomass samples—a level that was not previously achievable and is enabling better feedstock selection.

Similarly, wet chemistry compositional assays are being successfully downscaled by a factor of a hundred.[12,13] These allow for analysis of smaller samples and complement prior work with near infrared (NIR) and pyrolysis molecular beam mass spectrometry.[14–17] Lastly, screens of biomass-degrading enzymes have also been improved to facilitate screening for known or new degradative activities.[8,18–20] Together, these approaches are enabling optimization and combinatorial experiments that were not previously possible using biomass.

Introduction to Special Research Section

In this issue of *Industrial Biotechnology*, we present a Special Research Section comprising a collection of articles describing advances and progress in the development of methods and techniques for characterizing biomass. The section begins with a review by Foston and Ragauskas that discusses how improved measurements of

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chemistry, structure, and accessibility inform our evolving and improving insights into biomass recalcitrance. Next is a perspectives article by Langan et al. that presents insights into the power of expanded neutron beam analytical capabilities to provide new insights into biomass structure and conversion. This is followed by several papers on new or improved methods that target different aspects of biomass characterization. Biomass accessibility to enzymes is being seen as a key structural component to recalcitrance or conversion. Pattathil et al. present preliminary results using a new "glycomics" technique in which polysaccharide-epitope antibodies are used in an ELISA-type method to elucidate changes in plant cell wall chemistry, extractability, and interactions. Kulkarni et al, present an example of how specific polysaccharide changes in plant cell wall mutants of grasses influence the biomass. Chandra et al. describe improvements to the Simon's stain technique to decrease the quantitative variability of this straightforward measure of accessibility. Varanasi et al. show preliminary results in which an old measurement of strength using mechanical stress tests is updated to distinguish between *Arabidopsis* mutants. Finally, Tetard et al. describe a modification of atomic force microscopy to provide additional information on the plant cell walls at nanoscale.

This special issue is intended to illustrate the rapid development and diversity of techniques that can be applied to improve our understanding of biomass. I hope that the impact of these articles and the techniques being developed clearly illustrate the potential benefits of applying the results of improved biomass characterization to biofeedstock selection, growth, and handling as well as conversion using various pretreatments and biological processes. I believe that these measurements will also provide insights into the process development and optimization of various pyrolysis and gasification processes. Biomass characterization methods and techniques developed for lignocellulosic biomass will have additional value when extended into algal processes. They will also provide deeper insights as the biomass industry approaches the challenge of feedstock variability and quality.

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