AN EVOLUTION FROM PRETREATMENT TO FRACTIONATION WILL ENABLE SUCCESSFUL DEVELOPMENT OF THE INTEGRATED BIOREFINERY

Joseph J. Bozell

The current state of biorefinery development is focused almost entirely on the production of fuel ethanol. However, an ethanol-centric approach misses the crucial example set by the petrochemical industry. The ability to *fractionate* a raw material, rather than simply *pretreating* it, enables the parallel production of low value, high volume fuels and high value, low volume chemicals. By developing analogous fractionation processes for biomass, giving separate process streams of cellulose, hemicellulose and lignin, the biorefining industry will be able to recognize the synergistic advantages of producing both energy and profits.

Keywords: Biorefinery; Chemical products; Fractionation; Pretreatment

Contact information: Forest Products Center, Biomass Chemistry Laboratories, University of Tennessee, Knoxville, TN 37996 USA; mailto:jbozell@utk.edu

A Narrow Focus

Second-generation lignocellulosic biorefineries, and funding in support of their development, are overwhelmingly linked to production of fuel ethanol (EtOH). The default operation of lignocellulosic conversion processes has become almost dogmatic: the raw material is first subjected to a *pretreatment* designed to improve access to the polysaccharides present in the biomass. The polysaccharides in the pretreated material are hydrolyzed to monomeric sugars and fermented to EtOH, and the unfermented, lignin-rich residue is typically used as boiler fuel. Pretreatment is arguably the most important step in this process. If the pretreatment is ineffective, hydrolysis and fermentation become much less efficient, driving the overall process costs too high to be industrially viable. Many well-known pretreatment methods have been developed: dilute acid, steam explosion, hot water, AFEX, etc. But *access* to sugars is paramount - *separation* has not been a goal, as it can add costs that cannot be accommodated within the severe economic restrictions of a fuel-only operation. Indeed, pretreated material sent to hydrolysis and fermentation frequently contains significant levels of lignin and hemicellulose. Unfortunately, by giving biomass separation a lower priority, an important opportunity, and perhaps a requirement for developing a robust, integrated biorefining industry, is lost.

Looking at What Others are Doing

The petrochemical industry gives a good example. Historically, easy access to large, concentrated supplies of carbon in the form of coal, crude oil, or natural gas, coupled with a huge body of knowledge about how these carbon sources can be converted into more useful forms have been primary contributors to the economic and lifestyle advantages enjoyed by the industrialized world. Very simply, carbon is used for two things: the large majority is transformed into fuel for combustion reactions, generating the energy necessary for mobility, shelter, or power. Alternatively, carbon sources are refined to form the standard building blocks of the chemical industry, and used to synthesize the enormous number of chemical products vital to everyday life. While chemicals consume a much smaller portion of nonrenewable carbon, they possess an importance equal to that of energy production, in that they provide the economic driver to support the production of large amounts of low-value fuels. This synergistic interaction between energy from fuels and profits from chemicals has been a key component of the petrochemical industry for decades. Crucial to this interaction has been the parallel development of petrochemical *fractionation*, processes that can selectively convert the crude carbon source into specific process streams containing low molecular weight structures suitable for chemical production.

Biomass Applications

The biorefining industry will benefit from the same approach. For optimal use of domestic renewable carbon, a transition from simple pretreatment processes in an EtOH-centric model to fractionation processes within a multiproduct context is needed. Fractionation processes that provide selective access to individual process streams of cellulose, hemicellulose, and lignin will not only enable and improve the ability to manufacture fuels (by offering sugar streams of higher purity), but will lead to a profitable portfolio of chemical products able to provide financial incentive for an entire biorefining industry. Key characteristics of fractionation technology designed for multiproduct operation will include selective separation of each component of a biomass feedstock, easy access to and isolation of the components after separation, and recovery of each component in high yield. Organosolv processes have been identified as able to meet many of these requirements, as well as processes based on ionic liquids or multistage acid hydrolysis. Adoption of multiproduct fractionations as part of biorefinery development may increase the complexity and cost of operation. Nonetheless, a positive tradeoff results from inclusion of high value products because the biorefinery can use their higher profitability to offset more costly, but also more selective and flexible fractionation technologies.

Ongoing EtOH-centric processes based on simple pretreatment are valuable, as improved, and fundamental knowledge regarding cell wall deconstruction will benefit the production of biofuels and likely lower their cost. However, parallel understanding of biomass fractionation and processes for converting cellulose, hemicellulose or lignin to high value chemicals offer an additional financial upside that could relax some of the stringent economic hurdles faced by a fuel-only production model. Such research needs greater support from federal funding agencies in the short term. Improved fractionation technology for biomass, leading to profitable biorefinery operations, will provide the basis for a long-lived, robust biorefining industry.