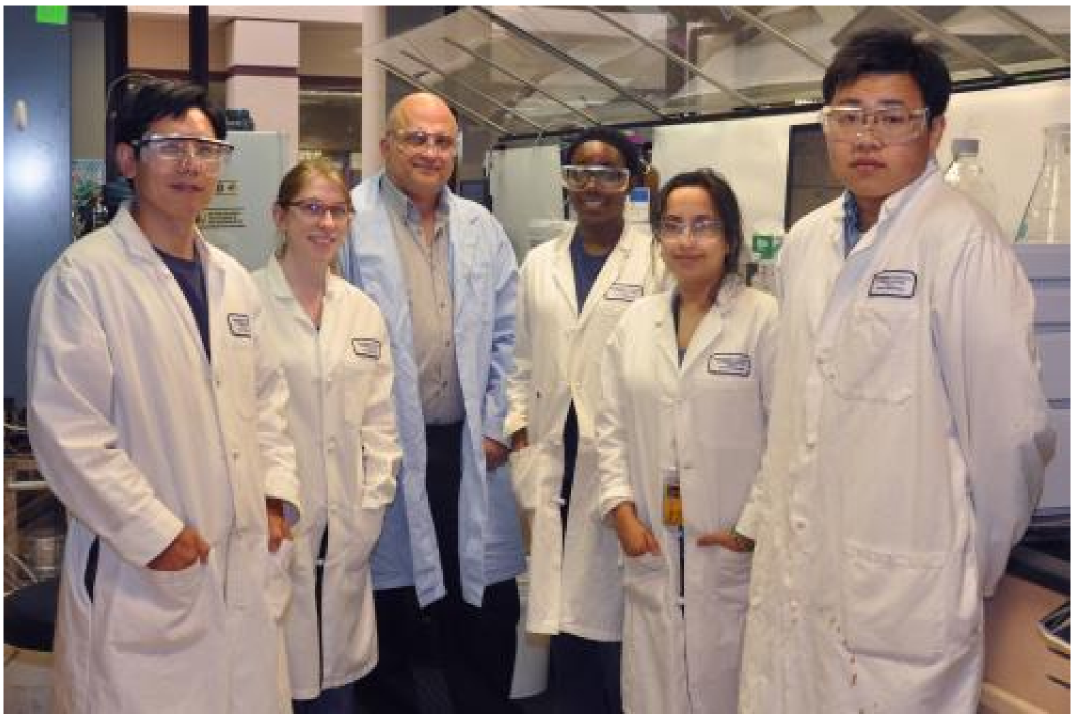
A tipping point for lignin

May 19 2014, by Morgan Mccorkle



Led by Art Ragauskas, the newly appointed Oak Ridge National Laboratory-University of Tennessee Governor's Chair in Biorefining, a multi-institutional team of researchers offers a new view of lignin in Science magazine. Pictured are members of Ragauskas's research group at Georgia Tech; (from left) Yunqiao Pu, Allison Tolbert, Art Ragauskas, Hannah Akinosho, Garima Bali, Xianzhi Meng.

(Phys.org) —Led by Art Ragauskas, the newly appointed Oak Ridge National Laboratory-University of Tennessee Governor's Chair in Biorefining, a multi-institutional team of researchers offers a new view of an organic polymer often dismissed as a worthless by-product. Their perspective appears in *Science* magazine as "Lignin Valorization: Improving Lignin Processing in the Biorefinery."

In the following interview Ragauskas discusses the team's arguments.

Q: What is lignin, and why has it been so difficult to study?

Lignin is a major component of woody biomass and most other terrestrial plants; it is nature's only true high volume aromatic polymer. It plays a crucial role in allowing the plant to guide water through the plant cell wall, and it also provides structure and defensive properties to plants. Unlike most other natural polymers that we have on the planet, it is not well ordered. It lacks the secondary and tertiary structures found in in well-organized polymers like DNA or cellulose. For that reason it's been hard to understand.

Q: How has the scientific understanding of lignin changed in recent years?

A set of strategic investments from the Department of Energy and other agencies, including the three Bioenergy Research Centers established by DOE's Office of Science in 2007, has helped scientists better understand lignin as they study ways to reduce the recalcitrance of biomass of cellulosic ethanol plants. For instance, researchers at the BioEnergy Science Center (BESC) have been examining how plants such as switchgrass or poplar trees can be more easily broken down and turned into biofuels via biological approaches.

The scientific community's increased attention on biofuels has allowed for the development of more precise analytical tools for lignin; these techniques combined with computational modeling have led to a deeper understanding of this complex polymer. We now know that we can drastically change the structure of lignin using genetic engineering. We can also change or minimally alter the structure during ethanol production, and we know that lignin will become a growing resource as we produce more bio-based fuels.

Q: You reference a saying in the pulp industry that 'one can make anything from lignin except money.' How is that attitude changing?

This review set out to describe a set of developments over the past few years that represents a tipping point in the prospects for lignin as a viable, commercially relevant sustainable feedstock for a new range of materials and uses. One development is that several world-class cellulosic biorefineries are starting to come online. To use lignin for a large-volume, high-value application, you need to collect it, process it and separate it. The cellulosic ethanol industry will do that. Right now they have to burn some amount of lignin as part of the production process, but there's 50 percent or more in excess, which is currently a waste product. People are begging for answers for this.

We're at the point now where we can ask the question—can we change the structure of lignin to reduce recalcitrance of biomass so we can get the polysaccharides for fuels and also have a valuable precursor for chemicals, fuels and materials? Many of us would argue that the time has come for this.

Q: The review discusses a wide range of potential uses for lignin, from low-cost carbon fibers and engineered plastics to chemicals and fuels. In your opinion, which

application is positioned to have the biggest impact?

My first pick would be carbon fibers because the volume is so large. Some models suggest that more than 40-50 percent of the structural steel mass in a vehicle could be replaced with carbon fiber composite materials. However, to realize this goal, low-cost manufacturing of carbon fibers on the order of hundreds of thousands of tons per year is needed at the commercial scale. Conventional carbon-fiber precursors are too costly for most such applications. Lignin from cellulosic biorefining operations could become a preferred precursor for carbon fiber synthesis but our current understanding of the fundamental chemistry involved in this process is limited.

We need to engineer plants that have specific properties; tailor extraction processes so they have minimal impact to isolating lignin and then run the material through carbon fiber manufacturing processes. Researchers at places such as Oak Ridge National Laboratory are working on achieving this goal.

Q: What additional research is needed to accelerate lignin's transition into commercial products? How close are we realizing its full potential?

Genetic engineering, if coupled with process chemistry, could be one of the keys to unlock lignin's potential. Seven or eight years ago if we wanted to study lignin, we had to use lignin from a pulp or paper industries. At that time few people had access to transgenic lignin specifically tailored for an application. Now access to re-engineered lignin is growing.

It's like we're beyond the time of Christopher Columbus. We know there is a New World out there. We've landed at Plymouth, built a little community, and now we're looking out west realizing there's a tremendous opportunity here. How much? We don't know yet, because we don't know where the Mississippi is, where the Rockies are. But from what little bit we see, we certainly know there's a really exciting opportunity here.

More information: "Lignin Valorization: Improving Lignin Processing in the Biorefinery." Arthur J. Ragauskas, Gregg T. Beckham, Mary J. Biddy, Richard Chandra, Fang Chen, Mark F. Davis, Brian H. Davison, Richard A. Dixon, Paul Gilna, Martin Keller, Paul Langan, Amit K. Naskar, Jack N. Saddler, Timothy J. Tschaplinski, Gerald A. Tuskan, and Charles E. Wyman. *Science* 16 May 2014: 344 (6185), 1246843 [DOI: 10.1126/science.1246843]

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