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Agricultural and Food Chemistry Contributions to Fulfilling the Promise of Biofuels

ACS Publications presents a Virtual Issue on Biofuels, an online compilation between *Energy & Fuels*, *Environmental Science & Technology*, and the *Journal of Agricultural and Food Chemistry* found at http://pubs.acs.org/page/vi/2010/biofuels.html. Featuring peer-reviewed papers published in 2009 and 2010, the research shows progress on utilizing biomass for fuel production, a hotbed of research with global implications for agricultural, energy, and environmental policy. Editors Jerald L. Schnoor (*Environ. Sci. Technol.*) and James N. Seiber ([*J. Agric. Food Chem.* (*JAFC*)], and Associate Editor Robert Weber (*Energy Fuels*) comment on their selection of these papers in editorials appearing in their respective journals and on the Biofuels Website. As interest in biofeedstocks for energy and material grows, these three journals encourage continued submission of high-quality and impactful manuscripts.

Note: papers in the Biofuels Virtual Issue are indicated in the below text both as citations and hyperlinks by digital object identifier (DOI; 10.1021/zzXXXXXXX for all ACS journals, where "zz" is the journal id ("jf" for *JAFC* and "XXXXXXX" is the manuscript number) in the HTML version. Readers can use the DOI to locate any ACS paper online in two ways: (1) the search box at the top right of the ACS journal (and Symposium Series) Webpages permits entry of a DOI (e.g., http://pubs.acs.org/); (2) direct your browser to http://dx.doi.org/, where "DOI" should be replaced by that in question (zzXXXXXXX) to electronically locate the paper.

The promise of biomass-based fuels and energy for the future has caught the public's attention perhaps more than any single issue in science and technology in recent years, with the possible exception of global warming and sustainability, to which biofuels and bioenergy are integrally linked.

Agricultural and food chemists have much to contribute in such areas including basic understanding of the composition of biomass, environmental impacts, and here and now applications. Challenges surrounding the conversion of plant cellulosics and lignocellulosics and of plant- and animal-derived lipids to liquid and gaseous biofuels as well as biobased products are particularly intriguing. Methods for processing biomass feedstocks that take into account the environment, human health, and the need to protect the food/feed supply, as well as being profitable and resource conservative, are at the forefront of interest among scientists and venture capitalists alike (*1*−*3*) (*J. Agric. Food Chem.* DOI 10.1021/jf800250u, *J. Agric. Food Chem.* DOI 10.1021/jf8006695, *J. Agric. Food Chem.* DOI 10.1021/jf063297e). Research is also needed on ways to recover energy and biobased products from the ubiquitous plant polymer lignin and from other plant components that are recalcitrant to fermentation; the production of fuels and fuel systems other than ethanol; and the development of thermal or catalytic methods to produce gas or liquid fuels or to produce nonfuel byproducts (solvents, monomers, biopolymers) as part of plant-based biorefining. Challenges exist as well in understanding the composition of the plant cell wall. New uses for byproducts such as lignin and its phenolic metabolites and glycerol are actively sought to make biorefining profitable, recognizing that success in this field will rely on generating value-added by- or co(bio)-products as well as biofuels. Also needed is a greater understanding of plant biosynthetic and metabolic pathways and the coupling of genomics, proteomics, metabolomics and related technologies to modifying synthesis and metabolism in ways that can benefit the needs of mankind without adversely affecting the health and safety of the environment. As new feedstocks are considered, grasses, algae, lipids, etc., additional questions will arise that agricultural and food chemists are well suited to address, particularly by working in partnership with molecular biologists, engineers, ecologists, and those in other disciplines.

JAFC added Biofuels to its "Biobased Product" category with a Spotlight issue published in June 2008 to capture agricultural and food chemistry content addressing bioenergy, biofuels, and related science. The perspective by Orts et al. (*1*) captures many of the references in *JAFC* and other journals through 2007. By the end of 2009, there were 48 papers published in the expanded category, and in 2010 there were 30 published as of the October 13th issue. Additional manuscripts addressing aspects of this topic can be found in other categories in *JAFC*, such as Analytical Methods and Environmental Chemistry.

This Virtual Issue will focus on manuscripts published in 2009 and 2010 relating to biofuels in *JAFC*, along with content from *Energy & Fuels* and *Environmental Science & Technology*, in order to highlight a few of the recent advances in the agricultural and food chemistry of biofuels and biobased products.

Although corn is by far the major feedstock crop for fuel ethanol in the United States, sorghum provided about 4% of the feedstock in 2009. In the area of feedstock improvement, Wu et al. (*4*) (*J. Agric. Food Chem.* DOI 10.1021/jf101555d) investigated plant breeding to improve the attributes of sorghum cultivars for maximized ethanol yields and improve value for feed uses as well.

In the area of alternative feedstocks, the work of Agger et al. (*5*) (*J. Agric. Food Chem.* DOI 10.1021/jf100633f) makes a strong case for bran byproduct from corn grain processing. Millions of tonnes are produced annually, and the recalcitrance of bran makes it of low value as a biofuel precursor or for animal feed and other existing markets. Using targeted enzymatic hydrolysis, xylose-based five-carbon sugars were produced that can be used directly for biofuel production and food additives. Another alternative feedstock, *Miscanthus giganteus*, is receiving attention (along with switchgrass, Napier grass, and other fast-growing and prolific grasses) as a feedstock.

Villaverde et al. (*6*) (*J. Agric. Food Chem.* DOI 10.1021/jf900071t) explore the extraction of sterol and aromatic biomolecules from the bark and core of *Miscanthus*, which could be recovered before the conversion of the bulk of the plant matter to biofuels. The chemicals extracted prior to conversion have potential uses as feedstock for nutraceutical and pharmaceutical

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production. Feather meal, a byproduct of the poultry industry, represents still another potential feedstock, according to Kondamudi et al. (*7*) (*J. Agric. Food Chem.* DOI 10.1021/jf900140e). Fats extracted from this meal were subjected to transesterification reactions similar to those in use for vegetable oils to produce biodiesel. An annual production potential of over 2.2 billion liters of biodiesel worldwide has been estimated from feather meal alone. Coffee grounds (*8*) (*J. Agric. Food Chem.* DOI 10.1021/jf802487s) are another common foodstuff waste that is a potential source of biodiesel precursor. These papers, and others proposing new sources for biofuels from familiar wastes, have attracted a lot of media attention.

In the area of biomass pretreatment, Fu et al. (*9*) (*J. Agric. Food Chem.* DOI 10.1021/jf903616y) researched the extraction of lignocellulosic wastes from agriculture, forestry, and paper production (estimated annual amount of 200 billion tonnes) with ionic liquids to remove up to 50% of the lignin, representing the recalcitrant component of lignocellulosic wastes, leaving behind a much enriched cellulosic fraction that can then be converted more efficiently to bioethanol and other biorefinery products.

Shrestha et al. (*10*) (*J. Agric. Food Chem.* DOI 10.1021/jf900345n) reported the use of brown-, white-, and soft-rot fungi to enzymatically break down the lignocellulosic fraction from corn fiber and other recalcitrant byproducts to increase the release of sugars that are convertible, by fermentation, to bioethanol. Brown-rot facilitated fermentation resulted in enhanced ethanol yields and a residue useful as an animal feed, in effect extending the production of biofuels and useable biomaterials from corn.

Sugar cane bagasse, the material left following extraction of sugar, is another potential biomaterial feedstock with both large annual production and ready availability in an aggregated form from sugar refineries. Peng et al. (*11*) (*J. Agric. Food Chem.* DOI 10.1021/jf900986b) report on the extraction, fractionation by graded ethanol precipitation, and chemical analysis of the hemicellulosic content of sugar cane bagasse. Xylan derivatives with potential use as dietary fiber additives to cereals and polymeric hydrogels could be recovered in this way.

Sluiter et al. (*12*) (*J. Agric. Food Chem.* DOI 10.1021/jf1008023) provide a general review of the chemical composition of cellulose, hemicelluloses, and lignin, the primary components of plant matter and of the plant cell wall, including lignocellulosics from biofuel production, woody pieces from forest thinning and paper production, and grasses. The authors trace changes in analytical methodology through time to the present evolution of procedures offered by the U.S. Department of Energy's National Renewable Energy Laboratory.

As the field of biofuels evolves, agricultural chemistry finds more and more applications to developing and refining processes for efficiently converting biomass to useful products, while avoiding such trade-offs as "food versus fuel" or environmental resource depletion. In many respects, we are just out of the starting gate in terms of realizing the full potential of biorefining and the resulting bioeconomy predicted by the end of the 21st century. The papers cited here from *JAFC* represent just a sampling of those published in the past two years, but they illustrate the point that agricultural chemists have rolled up their sleeves and are conducting highly relevant studies that are necessary to move the field along. A "magic bullet" breakthrough that can accelerate the commercialization of biomass to biofuel conversion would be most welcome, but more realistic are the types of focused studies that improve and expand upon prior work represented in this sampling of articles. Maybe the "magic bullet" is already in the pipeline awaiting publication—STAY TUNED!

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James N. Seiber, Editor
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