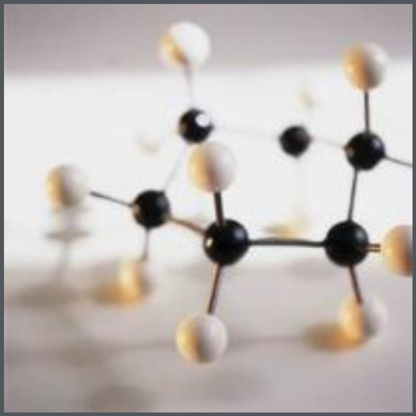
Conversion Technologies for Advanced Biofuels – Carbohydrates Upgrading

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy






Report-Out Webinar

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Bio-oil Production – Presenter Information

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2002 – present	Pacific Northwest National Laboratory
2001 – 2002	Phytagenics

Ph.D., Biochemistry, University of Texas Health Science Center at San Antonio, 2000

B.S., Biochemistry, Washington State University, 1995

- Current work focuses on proteomic analyses to identify proteins important in fungal hyperproductivity and algal lipid biosynthesis.
- Prior experience with expression of heterologous proteins in plant tissues and protein engineering and kinetic analysis of a tricarboxylic acid enzyme in yeast.

Biological Conversion of Sugars to Hydrocarbons – R&D Barriers

Selection of target hydrocarbon molecules

- Research efforts become diluted without determining optimal hydrocarbon or precursor molecules for biosynthesis from sugars

Construction/selection of microbial production system

- Current microbial systems for hydrocarbon biosynthesis are not effective production organisms (low titer, rate and yields)

Efficient carbon utilization

- Industrial processes will require utilization of all sugars and optimized sugar to hydrocarbon conversion

Product Separation

- Industrial separation processes are energy intensive and often inefficient

Biological Conversion of Sugars to Hydrocarbons – R&D Activities

- **Engineering or discovery of robust host organisms for production**
  - Applications in metabolic engineering and synthetic biology
- **Efficient 5-carbon sugar utilization**
  - Optimize stress management mechanisms for host organism in the presentence of limited six carbon sugars
  - Identify cellular transporters and regulators required for maximum sugar to hydrocarbon conversion
- **Eliminate production of alternate metabolites**
  - Identify highly effective bioconversion pathways for testing in a diverse array of host organisms
- **Analytical Tool Development**
  - Develop tools for measurement of low level inhibitors (ppm/ppb)
  - High-throughput metabolic flux analysis and redox balance measurements

Biological Conversion of Sugars to Hydrocarbons – Crosscutting Issues

Feedstocks

- Organism design for optimized tolerance to real-world hydrolyzes (i.e. hosts that perform well in the absence of pristine sugar streams)

Catalysis (strain development and discovery)

- Improving end product tolerance
- Development/discovery of organisms that metabolizes inhibitor molecules

Separations

- Increase efforts in fundamental separation science and membrane development, flocculation and coagulation chemistry
- Process integration and collaboration with upstream processes such as organism or pathway design

Techno-economic and life cycle analyses for:

- Identification of optimal hydrocarbon molecules for production
- Proposed separations unit operations

Catalytic Conversion of Sugars to Hydrocarbons – R&D Barriers

- **Feedstocks and preprocessing**
  - Desirable intermediates can be made from many biomass feeds using various pretreatment and deconstruction strategies including enzymatic and non-enzymatic hydrolysis, but feedstock reliability in composition is an issue
- **Processing**
  - The co-design of upstream processes for biomass deconstruction – which determine the slate of intermediates and contaminants – with the downstream catalytic processes to convert intermediates to fuels is important.
- **Catalyst Development**
  - More robust catalysts are needed to handle a wider range of biomass-derived inputs and contaminants, including sulfur, nitrogen, and ash.
- **End Product Concerns**
  - Blending and certification specifications for fuels from oxygenated intermediates are needed.

Catalytic Conversion of Sugars to Hydrocarbons – R&D Activities

- **Increase fundamental R&D on developing efficient pathways to produce intermediates amenable to upgrading and efficiently utilize reactive intermediates**
- **Assess the potential of using non-sugar intermediates**
- **Optimize systems for recycle and recovery of reagents used in processes**
- **Design catalysts for conversion in high temperature concentrated sugar solutions**
- **Discover mechanisms for deoxygenation of carbohydrates with minimum H2 input**
- **Improve selectivity to desirable fuel components**
- **Improve catalyst lifetime and durability**
- **Increase interagency activity to help define blending and certification specifications**
- **Increased focus on sensitivity analysis to guide research**
- **Develop analytical tools to quantify species in mixtures**

Catalytic Conversion of Sugars to Hydrocarbons – Crosscutting Issues

- **Feedstocks**
  - Study pre-conversion techniques for removal of deleterious compounds in the raw biomass feed and reduction of comminution needs
- **Catalysis**
  - Understanding catalyst fundamentals to fine-tune activity and selectivity and minimize deactivation
- **Separations**
  - Design at-temperature separation processes and reactive membranes to clean intermediate/product streams
- **Techno-economic and life cycle analyses:**
  - Economical closed-loop processes are needed to produce cost-competitive products and fuels.

Chemical Upgrading

- Mercurius Biofuels, Ethyl levulinate intermediate, www.mercuriusbiofuels.com
- Bond et al., 2010. Conversion of GVL to Liquid Alkenes *Science,* 327, 1110.
- Huber, et al. 2006. *Catalysis Today,* 111, 119.
- James, et al. 2010. HMF to Biofuels. *Energy Environ. Sci.*, 3, 1833.

- Conversion of corn stover to jet fuel (Virent)
- Biomass to oxygenated intermediates upgraded to fuels and chemicals (Virent)
- National Advanced Biofuels Consortium (NABC)

Biological Upgrading

- Synthesis of hydrocarbons reviewed in Ladygina et al., 2006. *Process Biochem*. 41, 1001.
- Alkane production in *E.coli*, Schirmer et al., 2010. *Science* 329, 559.
- Polyketide pathway for fuel precursor molecule production, Katz et al., 2010. US2011/0021790A1.

- Upgrading of sugars to diesel (HCL Cleantech/LS9)
- Production of farnesene (Amyris)
- TAG production by algae (Solazyme)