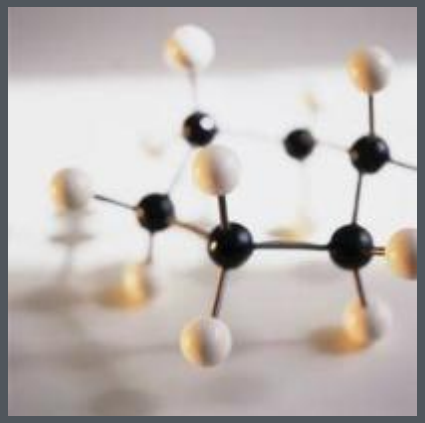
Conversion Technologies for Advanced Biofuels – Carbohydrates Production

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



Report-Out Webinar

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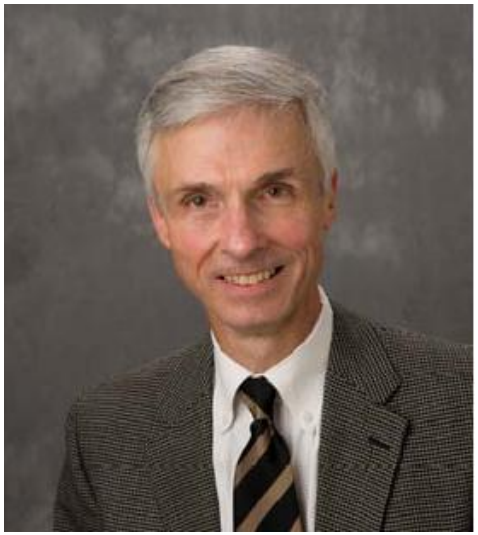

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Pretreatment & Enzymatic Hydrolysis – R&D Barriers

➢ Feedstock Variability and Preprocessing

- Uniform feedstock formats – impacts on multiple pretreatment processes/severities
- Feedstock impacts on biological/catalytic conversion (inorganics, extractives, lignin)
- Feedstock variability impacts on pretreatment process/severity requirements

➢ Pretreatment

- Fundamentals of pretreatment chemistry still not well characterized
- Fractionation may be more important for HC processes – process development
  - High concentration, solids-free sugar streams desired
- Cost benefit of more/less severe pretreatment conditions not well understood
  - Catalytic HC process may utilize broader range of soluble intermediates

Pretreatment & Enzymatic Hydrolysis – R&D Barriers (continue)

➢ Enzyme Science & Intermediate Conversion

- Better understanding of sources and mechanism of hydrolytic enzymes is needed.
- Great need for high sugar concentrations in HC processes
- Integrated pretreatment/enz. hyd. process development in HC processes
- Lignin effects (enzyme types, solubilization, inhibitory compounds)
- Inhibitor effects on HC-producing organisms/catalysts

➢ Separations

- Anticipate a greater need for separations in HC processes
  - Intermediates concentration/clean-up and product recovery
- Low sugar concentration hydrolyzates require extensive purification/clean-up
- Sugar concentration processes are highly capital/energy intensive
- Solids complicate sugar concentration and product recovery schemes.

Pretreatment & Enzymatic Hydrolysis – R&D Activities

- **Feedstocks**
  - Mitigate inorganics and extractives
  - Design modified feedstock to reduce recalcitrance
  - Investigate microbial pre-processing for efficient dowstream conversion
  - Densification for reduced transport costs
- **Pretreatment**
  - Multiple options for different feedstocks and HC production pathways
  - Specific focus on fractionation for high-concentration intermediates production
- **Enzymatic Conversion**
  - Investigate utility of lignin degrading enzymes
  - Design enzyme that resist inhibitors generated from pretreatment
  - R&D on enzyme action during mild pretreatment (thermal and pH stability)
- **Separations**
  - High-solids separations and *in-situ* phase separations
  - Inhibitor removal (low-fouling membranes and mesoporous structures)
  - C5/C6 sugar separation/concentration

Non-Enzymatic Routes to Carbohydrates & Sugars – R&D Barriers

Feedstock Variability and Preprocessing

- Accepting diverse feedstocks with varying moisture contents
- Identifying desired traits for different feedstocks relevant to different conversion processes
- Removing only the desired portion of biomass from the field

Processing

- Product selectivity and control are largely dependent upon individual process specifications.
- Strongly hydrogen-bonded biomolecules require severe conditions to digest and corrosion and material handling issues arise when using strong acids and bases.
- Scale-up is not straightforward, as the majority of non-enzymatic sugar production routes are unproven at anything above demonstration scale

Separations

- Developing separation capabilities for removing hydrophobic lignin from hydrophillic sugar stream and for removing co-solvents from biomass hydrolyzate streams

Non-Enzymatic Routes to Carbohydrates & Sugars – R&D Activities

- **Focus research and development on overcoming recalcitrance**
- **Develop efficient biomechanical methods for processing raw biomass to obtain uniform, non-recalcitrant, easily densified products**
- **Design processes to minimize sugar destabilization/degradation during acid hydrolysis**
- **Perform pilot scale R&D on separating water, acids and bases from biomass hydrolyzates at high solids loading (>20% w/w) with and without solvent**
- **Perform modeling to assess the impact of impurity build-up at commercial scale**
- **Develop better analytical methods for evaluating feedstocks and contaminants in sugar/product streams**

Pretreatment & Enzymatic Hydrolysis – Cross-Cutting Issues

- **Feedstocks**
  - Mitigate inorganics (ash, metals salts, etc.)
  - Pre-processing/densification/formatting and feedstock hubs
- **Catalysis (biocatalysis)**
  - Robustness to hydrolyzates; aromatics formation, phenolics
  - Fundamental studies to ascertain why glycans and C6 oligomers decrease cellulase activity
  - Design new hydrolytic enzymes to work synergistically in mild pretreatment conditions
- **Separations**
  - Post pretreatment, and post hydrolysis separation of sugars from solids for effective production concentration
  - Design integrated processes that require minimal washing of solids
- **Techno-economic and life cycle analyses**
  - Design rigorous models that include unique needs of hydrocarbon fuel processes; re-tasking of existing infrastructure for HC fuels production (pulp mills, corn ethanol plants, etc.)

Overall Cross-Cutting Issues

Feedstocks

- Mitigate inorganics (ash, metals salts, etc.)
- Pre-processing/densification/formatting and feedstock hubs

Catalysis & Biocatalysis

- Design 1-step catalytic systems for sugar production (co/counter current fractionation)
- Fundamental studies to ascertain why glycans and C6 oligomers decrease cellulase activity
- Design new hydrolytic enzymes to work synergistically in mild pretreatment conditions

Separations

- Post pretreatment, and post hydrolysis separation of sugars from solids for effective production concentration
- Design integrated processes that require minimal washing of solids

Techno-economic and life cycle analyses

- Design rigorous models that include unique needs of hydrocarbon fuel processes; re-tasking of existing infrastructure for HC fuels production (pulp mills, corn ethanol plants)