Feedstock Logistics and Preprocessing R&D at INL

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INL’s Biomass Feedstock National User Facility

Feedstock logistics, preprocessing, and modeling capabilities spanning bioenergy supply chain

- Feedstock Supply & Logistics
  - Integrated landscape management
  - Resource mobilization
  - Techno-economic and life cycle assessments

- Biomass and MSW Variability Management
  - Feedstock characterization
  - Interfacial property measurement
  - Post-harvest physiology & chemistry solutions

- Mechanical Preprocessing R&D
  - Bench to pilot scale preprocessing and fractionation
  - Artificial intelligence-based materials preprocessing

- Scale-up for Conversion-Ready Feedstocks
  - Testing, development, and scale-up of preprocessing technologies
  - Computational modeling and digital twins for rapid scale-up
Feedstock Supply Chain Challenges

What are biorefineries up against?

- Flowability, feeding and handling
- Feedstock variability
- Equipment uptime/downtime
- Lack of equipment performance data
- Lack of feedstock specifications
Feedstock Supply Chain Challenges

**Feedstock Supply and Logistics**
- Production
- Harvest & Collection
- Long-Term Storage
- Transportation

**Preprocessing**
- Short-Term Storage & Queuing
- Size Reduction & Pelleting

**Conversion**
- Pretreatment
- Enzymatic Hydrolysis
- Conversion of sugar monomers to fuels/chemicals

*Images of various feedstocks and processing equipment are shown.*

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Updated Vision: Quality-by-Design Feedstock Supply Chain

• Develop value-add, transformative, economical and sustainable technologies to enable Quality-by-Design Feedstock Supply Systems from renewable and diverse carbon and energy sources for biofuels, bioproducts and biopower production

Uniform Format Feedstock Supply System
Stone Milling Approach
Simple supply systems that grinds, dries and densifies

Quality-by-Design Feedstock Supply System
Fractional Roller Milling Approach
Expands preprocessing operations:

• Enables access to new feedstocks
• Selective pairing of feedstock fractions and conversion processes based on feedstock quality
• Midstream for fractionation, merchandising, and value-add
Accelerating the Process of Innovation

Grist Mill Diagram

Whole Wheat Stone Milled Flour

Simplified Roller Mill Diagram

How Flour is Milled

- Bran
- Shorts
- Clear Flour
- Germ
- Patent Flour
Quality is an Issue for all Biomass Resources

**Forest Residues**

**Municipal Solid Waste**

**Corn Stover Bales**

- Raw Biomass DOES NOT meet Feedstock Specifications
- Biomass Resource Diversity and Variability Requires Preprocessing of Raw Biomass to Achieve Feedstock Specification
Less than 30% of Field-Run Corn Stover Meets Critical Biorefinery Quality Specifications

- Greater than 90% of Biomass Feedstock material must meet all conversion specifications
Variability is Inherent to Herbaceous Biomass

- Anatomical Fractions have variable response in mechanical and chemical processing
  - Leaves are pulverized upon impact
  - Husks and stalk need shear-based size reduction

Li et al., 2020, ACS Sus. Chem. Eng
Reconfigurable Fractional Milling Loop

• Multi-stage comminution and separations enables fractionation
  - Removal of soil
  - Separation of husks and leaves
  - Recycle to achieve a narrow size distribution

• Reconfiguration enables tailored fractionation for multiple feedstocks and conversion pathways
Anatomical Fractionation is Critical to Achieve Conversion Specifications

- Wood has many anatomical fractions with significant differences in ash concentration
  - Inorganics are responsible for slagging and fouling of catalysts in conversion
- The needles and bark (contained in the tops/branches) contain the most ash and their content changes with age
Multi-Stage Comminution Combined with Separators Enables Pine Residue Fractionation

Forest residues can now be separated into almost pure anatomical fractions that will reduce fines generation and energy consumption in downstream milling operations.
Developing Over-Belt Technologies for Separations and Material Characterization

• Separations and Sorting Vision Systems
  − Artificial Intelligence/Machine Learning powered systems
INL’s capabilities range from feedstock logistics, preprocessing, and modeling spanning bioenergy supply chain
  - Biomass Feedstock National User Facility designated in 2013

Feedstock quality specifications are critical to maximizing predictability of conversion

As industry moves to more diverse resources such as MSW, wet wastes, and gaseous feedstocks to support a circular carbon economy, more emphasis is needed to reduce variability in:
  - Flowability and Handling
  - Fractionation (critical to maximizing revenue)
  - Stability

Feedstock management is critical to biorefinery performance
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