Alternative Feedstocks for the Petrochemical Industry from Biomass Lignins

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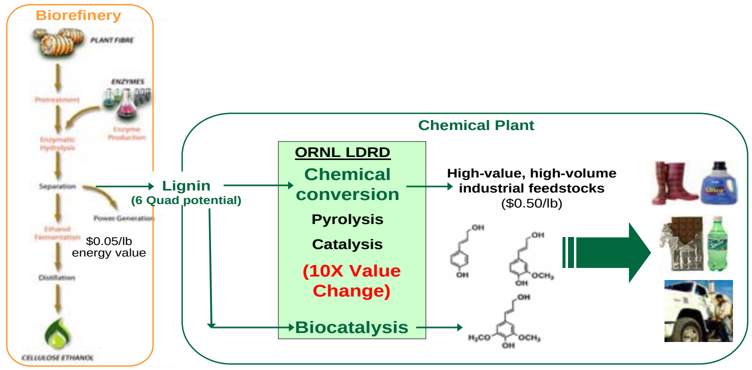
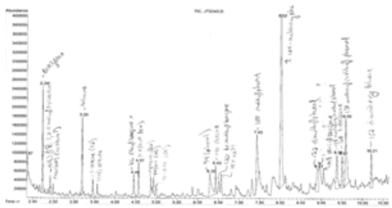
Overview

This effort consists of initial studies toward the use of biomass lignins to extend or replace the 3.6 EJ/y of fossil resources used in the US as feedstocks in the production of chemicals. We aim to exploit a new capability developed by ORNL for "cleaning" lignin to convert this current high-volume byproduct material into useful feedstocks for petrochemical production. The work includes exploratory bench-scale studies of catalytic and biocatalytic processes that permit conversion of lignin into both aromatic and cyclic or aliphatic feedstocks, which are directly useful for producing a wide range of materials. Feedstock production from the lignin portion of biomass will complement the ongoing DOE initiative for cellulosic ethanol production. The production of high-value chemicals, in addition to fuel, in a biorefinery is expected to improve the process economics.



Pyrolysis: Tests with contaminant-free lignin are promising

Compounds identified among major peaks:
- Benzene
- Toluene
- Xylenes
- Styrene
- 2-methoxyphenol
- Methoxymethylphenol
- Ethylmethoxyphenol
- Isoethylmethoxyphenol



Experiments with flax lignin:
- Good yield
  - 32% as resin feedstock at 400ºC; 60% at 500ºC
- Several identifiable target compounds
  - Many high-volume industrial chemicals
- Product mix appears attractive for downstream processing (similar to oxygenated refinery stream)

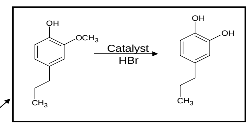
Catalysis: Quantitative conversion of lignins achieved by Lewis acid treatment

Catalytic Hydrogenation leads to breaking of ether bonds and partial reduction of aromatic rings.

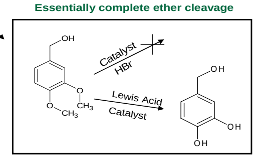
Lignin (Purified)

Model Compounds

Low Molecular Wt. Compounds



Essentially complete ether cleavage



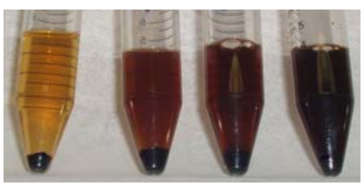
Lewis acid reactions can be carried out under mild conditions (-78ºC to RT) and the product can be separated.

The reagents, solvents, and byproducts can be recycled.

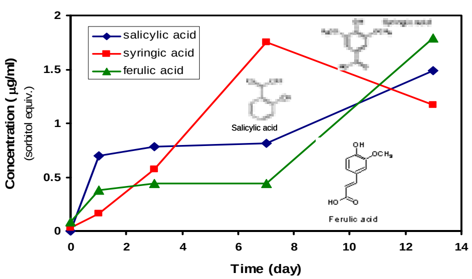
A Lewis acid catalyst has been found to be superior to Bronsted acids (HBr)

Microbial Conversion: Experiments are based on unique consortia

- Consortia obtained from soil samples
  - Most lignin in nature is degraded in soil
  - Different source than other microbes under study
- Initial testing showed remarkable results
  - Purified lignin incubated with cultures in a minimal medium (only lignin to eat)
  - Lignin solids fully dissolved in 6 days
    - ⇒ Rapid degradation of lignin!



Microbial degradation of Sarkanda grass lignin.



Controlled Test:
Useful aromatic compounds were produced during microbial degradation of Sarkanda grass lignin

With optimization, this finding could lead to bioprocesses or enzymes for lignin degradation to high-volume industrial aromatics.

Summary and Outlook

This work is developing multiple promising opportunities
- Pyrolysis
  - Excellent yield of priority chemicals
  - Good potential feed to chemical conversion processes
- Chemical Catalysis
  - Lewis acid catalysis converts lignin under mild conditions
- Biocatalysis
  - Soil consortia capable of rapid lignin degradation
  - Attractive potential source of enzymes
- Analysis
  - Interaction with industry has identified target chemicals with potential commercial viability

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