Biological Conversion of Cellulosic Biomass to Ethanol at UCR

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Outline

- How does transportation depend totally on petroleum?
- What are the alternative options to petroleum?
- How to make cellulosic ethanol?
- Our goal at UCR
Petroleum and Transportation

- Petroleum is single largest energy source in U.S. supplying ~38.5% of total energy
- About 2/3 of petroleum goes to transportation
- Transportation is almost totally dependent on petroleum (~96.4% in 2000) of energy needs
- The largest source of greenhouse gases comes from transportation, ~32.8% (The more fuel our vehicles burns the more greenhouse gases it emits)
- We use more petroleum than we produce –> 60% imported
- Most petroleum reserves are in unstable countries
Options to Reduce Petroleum Use

- More public transportation/Drive less miles
  - An important opportunity
  - Counter to historic trends
- Drive more efficient vehicles
  - Low hanging fruit not taken advantage of
  - Synergistic with new fuels
- Change the source of fuels
- Need to find alternatives to petroleum for transportation
  - Should seek sustainable fuels to avoid future transitions and reduced greenhouse gases
Sustainable Alternatives for Transportation

By Lee Lynd, Dartmouth
Convert Cellulosic Biomass into Ethanol

- **Existing resources**
  - **Agricultural wastes**
    - Sugar cane bagasse
    - Corn stover and fiber
  - **Forestry wastes**
    - Sawdust
  - **Municipal wastes**
    - Waste paper
    - Yard waste
  - **Industrial waste**
    - Pulp/paper sludge

- **Future resources**
  - **Dedicated crops**
    - Herbaceous
    - Woody
  - **Not sugar or starch crops such as used for making ethanol in Brazil and the U.S. respectively**
Billion Ton Supply of Cellulosic Biomass

- DOE and USDA recently estimated 1.3 billion tons of cellulosic biomass could be available
- Includes 368 million dry tons from forests and 998 million dry tons from agriculture
- Equivalent to about 130 billion gallons of ethanol – replace about 2/3 or more of 130 billion gallons of gasoline used annually
About Switchgrass

- Scientific name is *Panicum virgatum*
- Originally found across North America but was displaced by settlers’ crops and farmland
- Grows very quickly, and can reach over 2 meters tall
- Can be grown on land unsuitable for food crops
Municipal solid waste (MSW) in California

- ~51.3% of MSW in CA is cellulosic biomass
- The rich carbohydrate compositions of these cellulosic wastes
  ~36.4 million tons produced per year
- can provide a year round supply for ethanol production with zero to negative feedstock cost
Collection of 400-500 tons of “blue bin contents” daily
Overview – Blue Bin

Blue bin

Mechanical/ manual separation

Glass, plastic, cans

- residuals
  - landfill
- cans
  - PET bottles
  - Milk bottles
  - export

fibers

- residuals
  - cardboard
  - Mixed paper
  - newspaper
  - $0.00
  - export
  - 140-300$/ton

Landfill (ADC Final)
Overview – Green Waste

Greens

*tumbler*

Wood, big pieces

Woody waste

$7.50/dry ton

Burning facility

Grass, leaves...

treated

ADC green (Landfill)

$0.00

Grass waste (Farm)

$0.00
Cellulose-rich municipal solid waste fractions

Mixed paper
Cardboard
ADC final
Woody waste
Grass waste
ADC green
Process Flow Diagram of Dilute Sulfuric Acid Pretreatment

Biomass → Dilute Acid Presoaking → Pretreatment

Pretreatment → Water Washing

Water Washing → L/S Separation

L/S Separation → Enzymatic Hydrolysis

Enzymatic Hydrolysis → Hexose sugars, Pentose

Hexose sugars, Pentose → Acid Posthydrolysis

Residue solids
Composition of raw MSW fractions

![Composition graph]

- ADC final
- Grass waste
- Woody waste
- ADC green
- Cardboard
- Mixed paper

Composition (%): other, ash, lignin, xylan, glucan.
Composition of pretreated MSW fractions

ADC final
Grass waste
Woody waste
ADC green
Cardboard
Mixed paper

Composition (%)

- other
- ash
- lignin
- xylan
- glucan
How Cellulosic Ethanol is Made

1. Biomass is harvested and delivered to the biorefinery.
2. Biomass is cut into shreds and pretreated with heat and chemicals to make cellulose accessible to enzymes.
3. Enzymes break down cellulose chains into sugars.
4. Microbes ferment sugars into ethanol.
5. Ethanol is purified through distillation and prepared for distribution.

Pretreatment

- Rapidly heating biomass to high temperature (100-200°C) with water or dilute acid
- Process breaks up the lignin and hemicelluloses making the cellulose more accessible
Enzymatic Hydrolysis

• The enzymes work to break down the cellulose and hemicelluloses into sugars (glucose and xylose)
• Optimal enzyme mixture need to be adjusted to each different kind of biomass material
Current Research Projects

- Diesel fuel from biomass – DARPA/Umass/Logos
- **Effect of different pretreatments on enzymatic hydrolysis of poplar wood and switchgrass** – US DOE
  - Lead Consortium with Auburn, Michigan State, NREL, Purdue, Texas A&M, U. British Columbia, and Genencor
- **Biological Conversion Of Municipal Solid Waste To Ethanol (MSW)**
- Pretreatment of cellulosic biomass for BioEnergy Science Center (BESC), $25million/yr DOE Center
- Continuous hydrolysis and fermentation – USDA
- Continuous fermentations of pretreated biomass - NIST
- Fundamentals of biomass pretreatment – Mascoma Corporation
- Evaluation of advanced plants – Mendel Biotechnology
Mission of UCR Ethanol Research

- Improve the understanding of biomass fractionation, pretreatment, and cellulose hydrolysis to support applications and advances in biomass conversion technologies for production of low cost commodity products
- Develop advanced technologies that will dramatically reduce the cost of production
Example Experimental Systems

Pretreatment tubes

Parr reactor

Fermentors

Pretreatment steam gun

HTP Pretreatment

Continuous fermentation train
Summary

- Petroleum is expensive and valuable
- It provides gas for our cars and other uses of energy
- It is a non-renewable resource
- Cellulosic are abundant, inexpensive, and sustainable
- Our lab is developing the processes to turn various sources of cellulosic biomass into bioethanol as an alternative transportation fuel.
Questions???