Biomass Conversion Research

U.S. Dairy Forage Research Center

Madison, WI

(Neal Martin, Center Director)

Value-Added Products from Forages and Bioenergy Crops

CRIS Project 3655-41000-004-00D

Current Personnel (SY):

Matt Digman (0.8)

Paul Weimer (0.7)

Mike Casler (0.2)

To be added (SY):

Peter Vadas (0.4)

Ron Hatfield (0.2)

John Ralph (0.2)

Mike Sullivan (0.2)

CRIS Project 3655-41000-004-00D

- Biomass Production, Harvesting and Storage
  - Agronomy
  - Breeding and Genetics
  - Harvesting and Storage
- Biomass Conversion
  - Pretreatments
  - Value-Added Co-products from Consolidated Bioprocessing
  - Fermentability Screening of Biomass Materials

On-Farm Pretreatment

- To generate a product that is more susceptible to enzymatic or chemical hydrolysis, for delivery to the biorefinery
- To add on-farm value to product

Collaborator: K. Shinners, UW-Madison

Pretreatment: Preliminary Results

	Treatment	% Theoretical
Reed	Control	41%
	H_2SO_4	77%
	$Ca(OH)_2$	85%
	Ozone	96%
Switch	Control	17%
	H_2SO_4	26%
	$Ca(OH)_2$	38%
	Ozone	44%

Theoretical efficiency based on ethanol production via SSF of hexose component of feedstock

Consolidated Bioprocessing to Value-Added Products

Biomass conversions to ethanol and other valuable products using anaerobic bacteria that produce their own fiber-degrading enzymes.

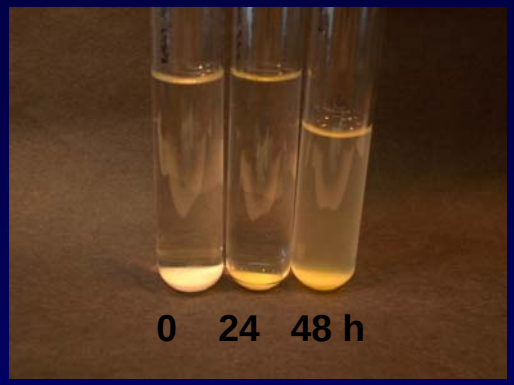
Potential advantages:

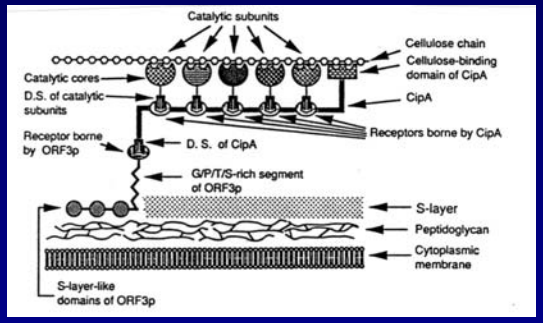
- **Eliminates need for separate enzyme-producing reactor**
- **Hydrolysis of both cellulose and hemicelluloses, and fermentation of both hexose and pentose sugars**
- **Potential for production of both ethanol and valuable co-products**

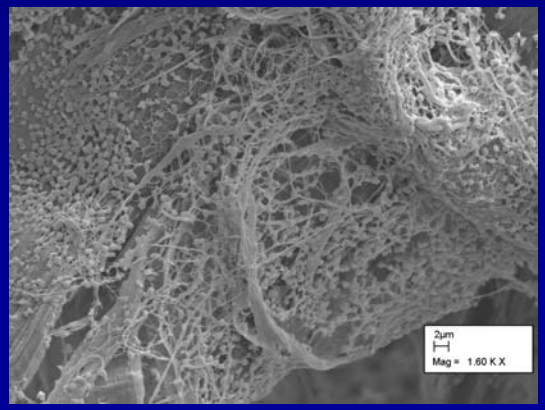
Exemplary organisms:

- ***Ruminococcus albus***
- ***Clostridium thermocellum***

CBP Bacteria employ a novel strategy for degradation of cellulosic biomass

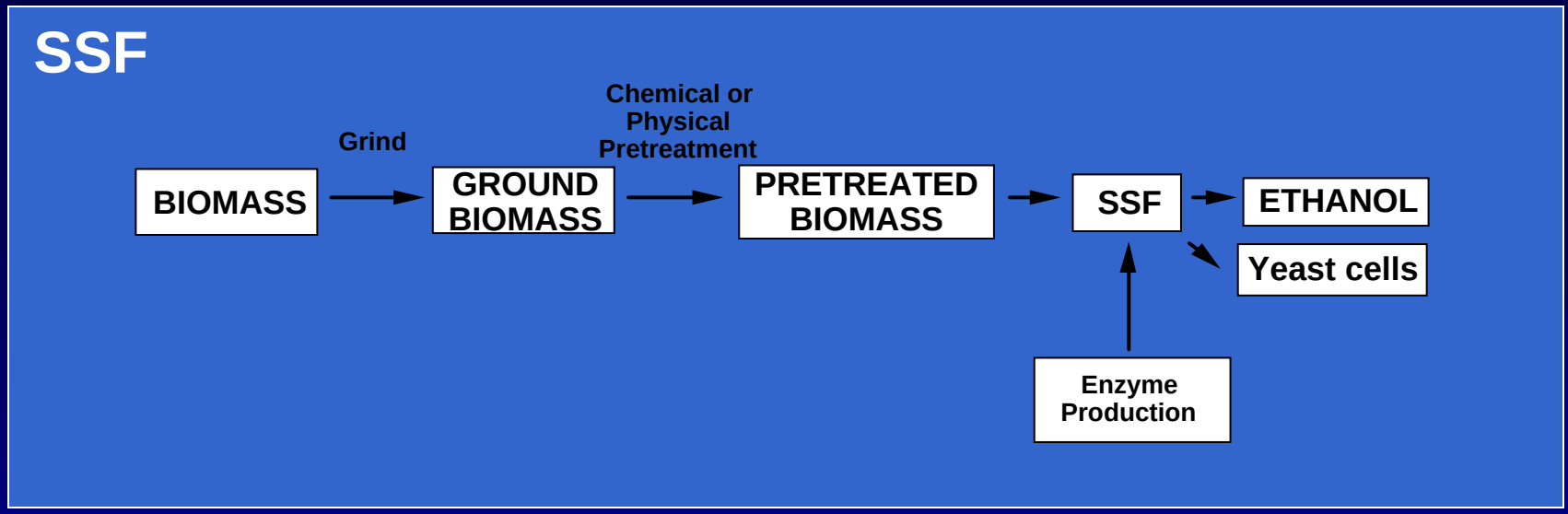


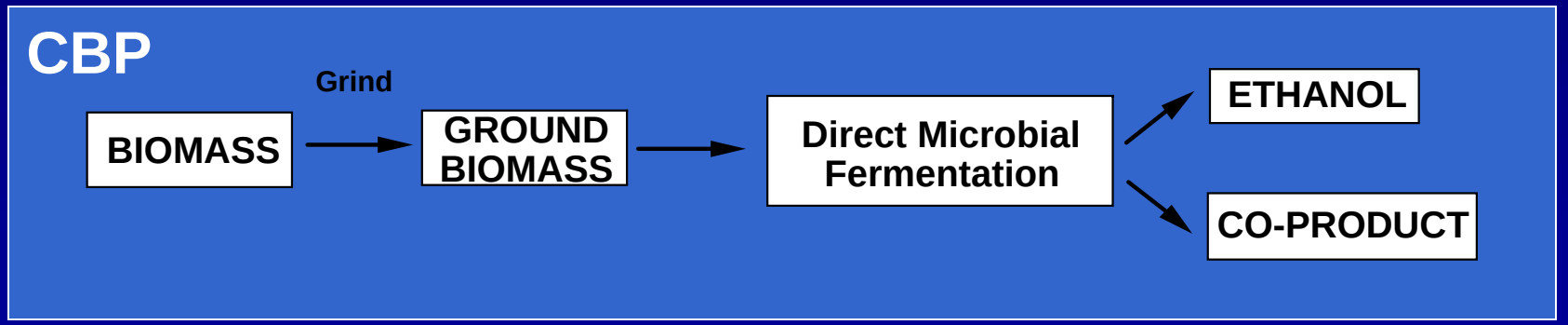




- Bacterial adherence required for active plant cell wall degradation
- Polysaccharide degradation mediated by cell surface-bound enzymes of extremely high specific activity, organized in discrete complexes
- Adherence mediated by novel extracellular polysaccharides

CBP vs. SSF


SSF
BIOMASS
Grind
GROUND BIOMASS
Chemical or Physical Pretreatment
PRETREATED BIOMASS
SSF
ETHANOL
Yeast cells
Enzyme Production


CBP
BIOMASS
Grind
GROUND BIOMASS
Direct Microbial Fermentation
ETHANOL
CO-PRODUCT

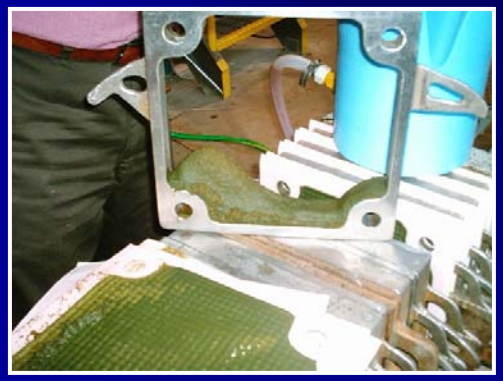
CBP Research at USDFRC

- **Fundamentals of CBP**

  Substrate utilization, Product partitioning, Gene expression (Collaborator: L. Lynd, Dartmouth)

- **Medium minimization**

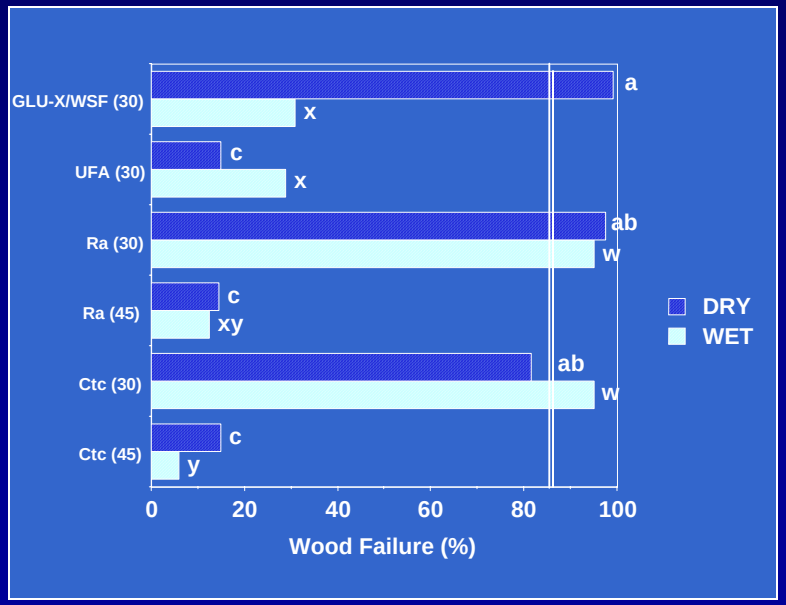
- **Co-product identification and development**



Novel Bio-based Adhesive

(collaboration with USDA-FS-Forest Products Lab)

Fermentation of cellulosic biomass yields ethanol and a solid residue (bacterial cells + EPS + unfermented fiber) that can serve as a plywood adhesive.



Adhesive can be used alone for dry applications, or can be used as a co-adhesive to replace a substantial portion of petroleum based phenol-formaldehyde adhesive resins.

Biomass Fermentability Screening
(Weimer)

- Developed rapid screen for fermentability of biomass based on gas production from mixed ruminal microbes
- Predicts CBP conversion potential, and can serve as a “first-cut” screen for SSF (w/ B.Dien)
- Identifies promising species and elite genotypes
- Allows determination of relationship between plant genotype and plant growth environment on fermentability of plant material

ARS collaborators

T. Springer (Woodward, OK)
K.P. Vogel (Lincoln, NE)
J. Hanson (Mandan, ND)
H.G. Jung (St. Paul, MN)
P.R. Adler (University Park, PA)
B. Dien (Peoria, IL)

Outside collaborators

W.R. Kenealy (USDA-FS-FPL)
J. Coors (UW-Madison)
C. Habeck (UW-Madison)
N. DeLeon (UW-Madison)

Bioconversion: Research Plans

- Pretreatments (Digman)
  - Optimize conditions (with B. Dien, NCAUR)
  - Apply at farm scale
  - Novel enzyme pretreatments (with X. Li, NCAUR)
- Bio-based adhesives (Weimer)
  - Improve production
  - Expand range of utility (with C. Frihart, USFPL)
  - Scale up for transfer of technology
- Economic and Environmental Assessments (Vadas)
  - Systems approach to integrate feedstock production and bioconversion of several bioenergy crops for reduced cost and environmental footprint