Integrated Process for Production of Succinic Acid from Biomass

BIO World Congress
June 17, 2013
MBI: Mission and Capabilities

- **Who we are:** Not-for-profit, founded in 1981, subsidiary of MSU Foundation

- **Mission:** Accelerate development, scale-up and commercialization of bio-based technologies

- **What we do:** develop and derisk early stage bio-based technologies, demonstrate commercial viability, transition to commercial partners

- **Capabilities:** biomass processing, strain engineering, bench and pilot fermentation development, downstream processing

MBI personnel & facility, - Lansing, MI
Key Challenges: Integrated Conversion of Biomass into Succinic Acid

- Biomass supply chain considerations
- Conversion of biomass to fermentable sugars
- Fermentation of biomass sugars
Logistics Challenge Visualized
The MBI Solution:

- Decentralized biomass processing
- AFEX™ pretreatment technology
- Omnivorous succinic acid producer
Decentralized Biomass Processing in AFEX™ Depots

- 50 – 200 tons/day of biomass
- Draw from 5-10 mile radius
- 7 to 15 depots per biorefinery
- Utilize existing infrastructure
- Foster rural economic development, ecological and social sustainability
The MBI Solution:

Decentralized biomass processing

AFEX™ pretreatment technology

Omnivorous succinic acid producer
AFEX Biomass Pretreatment

- Effective with variety of ag residues
- Dry-in, dry-out, no waste process
- 9x densification
- Stable, storable, readily transportable

Reaction → Expansion → Densification

Ammonia Recovery

Raw Biomass

Treated Biomass

AFEX Pellets
AFEX - Effective With Multiple Agricultural Residues

Glucan Conversion After Enzymatic Hydrolysis

Different Feed Stock

Switchgrass  Corn stover  Sugarcane Bagasse  Rice straw  Miscanthus  DDGS

Glucan conversion

0  20  40  60  80  100

Untreated  AFEX

mbi
AFEX – High Solids Fermentation

Pelleted AFEX treated corn stover

AFEX pellets (20% solids)

Concentrated sugar stream

Water + Enzyme

4 hrs, 50°C

Compatible with multiple commercial enzyme cocktails
Results shown above based on Novozymes Cellic® CTec3 + HTec3
The MBI Solution:

- Decentralized biomass processing
- AFEX™ pretreatment technology
- Omnivorous succinic acid producer
Key Challenges: Fermentation of Biomass Sugars

Utilization of mixed biomass sugars
- Natural or engineered
- Simultaneous or sequential
- Engineering a solution can be complex due to unique transport, metabolism and regulatory control for each sugar (glucose, xylose, arabinose, etc.)
Organism: *Actinobacillus succinogenes*

- Natural succinic acid producer
- Compatible with biomass sugars (simultaneous C5 & C6 utilization)
- Fully anaerobic fermentation (not a strict anaerobe)
- Highly adaptable to different raw material sources
- Successfully scaled to 3800L at MBI
- Demonstrated competitive titer, productivity and yield
## Integrated Conversion: Biomass to Succinic Acid

Production of Succinic Acid from AFEX pretreated corn stover + enzyme hydrolysis

Organism: Actinobacillus succinogenes

<table>
<thead>
<tr>
<th></th>
<th>EFT (h)</th>
<th>Succinic (g/L)</th>
<th>Glc (g/L)</th>
<th>Xyl (g/L)</th>
<th>Ara (g/L)</th>
<th>Yield (g succinic/ g sugar)</th>
<th>(% yield of theoretical)</th>
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</thead>
<tbody>
<tr>
<td>Hydrolysis</td>
<td>1027-76-3.4</td>
<td>72</td>
<td>NA</td>
<td>68</td>
<td>38</td>
<td>4</td>
<td>NA</td>
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<tr>
<td>pH adjusted, hydrolysate added to media+inoculum</td>
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<tr>
<td>Control</td>
<td>47</td>
<td>56</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>78</td>
<td>76</td>
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<tr>
<td>Corn stover hydrolysate</td>
<td>47</td>
<td>65</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>83</td>
<td>81</td>
</tr>
</tbody>
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- Integrated hydrolysis and fermentation – no intermediate washing step
- 20% solids loading
A. Succinogenes Mixed Sugar Utilization Rates

- Hydrolysate sugars utilized simultaneously
- Similar consumption rates
- Excellent yield
Similar Results With Corn Fiber

Production of Succinic Acid from AFEX pretreated corn fiber + enzyme hydrolysis + dilute acid hydrolysis

Mixed Sugar Fermentation.

Corn Fiber Hydrolysate and LFS
AFEX technology + distributed depots = effective solution to biomass supply chain challenge

- Dry in, dry out process with no liquid waste streams
- Low cost, stable, shippable biomass commodity
- Supports both rural economic growth and large scale biorefineries

AFEX effectively converts biomass to fermentable sugars

- Works with commercially available enzymes
- No need to for treatment between hydrolysis and fermentation
- Operating at 1 ton per day pilot scale now

A. Succinogenes efficiently converts biomass sugars to succinic acid

- Excellent fermentation performance on biomass hydrolysate
- Licenses available in some regions
Thank you for your time and interest

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