Addressing Biomass Supply Chain Challenges With AFEX™ Technology

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MBI: Mission and Capabilities

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

- **Mission**: Create meaningful societal benefits by collaborating with universities, governments and companies to accelerate the 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
Biomass Supply Chain & Pretreatment Challenges

- Low density of Ag residue biomass
- Expensive to transport long distances
- Often not situated close to desired biorefinery locations
- Collection area may not be practical
- Potential for spoilage
Logistics Challenge Visualized
Decentralized Biomass Processing

- 100–200 tons/day of biomass
- Draw from 5-10 mile radius
- Densified, stable, shippable
- Multi depots per biorefinery
- Utilize grain infrastructure
Potential AFEX Depots in Iowa

- Red circles represent potential 200 DMT/day (70,000 DMT/year) depots with rail access.
- Burgundy circles represent potential 200 DMT/day depots on major highways.

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AFEX Can Double Output From Existing Grain Production

By 2030:
- Global population will grow from 7 Bn to 8 Bn
- Middle-class to grow by staggering 3 Bn (1.8 Bn to 4.8 Bn)
- Per-capita caloric intake to increase by 20% in India
- Per-capita meat consumption to increase by 40% in China
- Number of vehicles doubles (1 Bn to 2 Bn)

Source: 2011 McKinsey Global Survey
AFEX Process Description

After AFEX treatment:

Biomass
Steam
Ammonia

Ammonia Strip and Recycle

Reactor 1

Reactor 2

Ammonia Strip & Fiber Expansion

Ammonia Strip & Fiber Expansion

Drying
Pelletizing

Treated biomass
AFEX pellets
Corn stover being processed in MBI’s AFEX pilot-scale reactor
Effective With Multiple Biomass Sources

Glucan Conversion After Enzymatic Hydrolysis

Different Feed Stock
- Switchgrass
- Corn stover
- Sugarcane Bagasse
- Rice straw
- Miscanthus
- DDGS

Glucan conversion
- Untreated
- AFEX

Switchgrass is effective with multiple biomass sources.
Production of Cellulosic Ethanol From AFEX Pellets

- 20-25% solids loading of AFEX pellets
- Saccharification using Novozymes CTec3, HTec3 enzymes, 48 hrs @ 50° C. (7mg/g biomass)
- Did not remove unhydrolyzed residue prior to inoculation
- SHF fermentation using public domain Z. mobilis strain
- Glucose completely consumed, xylose 80% consumed within 48 hours of inoculation
**AFEX Beef Cattle Trial Results**

Results of study of 24 Holstein steers (12 AFEX modified diet, 12 control diet) fed for 168 days from September 2013 – February 2014

- AFEX pellets palatable to steers
- Data confirms that AFEX pellets have utility as a partial substitute for corn grain in cattle diets
- No significant health difference between AFEX and control steers
- No significant difference in carcass quality properties
- No change in nitrogenous compounds in the meat
- Comparable weight gain observed

![AFEX-Fed Ribeye](image1.png) ![Control Diet Ribeye](image2.png)
AFEX Technology Highlights

Reactors & Process:
- Simple low-cost reactor design
- >95% Ammonia recycle
- Dry-in, dry-out – no waste streams
- Can be scaled between 5 and 200 tons/day

Results:
- Enables recovery of >70% of cellulosic sugars
- Pellets 9x more dense than raw biomass
- Produces stable, shippable, pellets
- Enables “hub and spoke” system of local biomass depots
- No detoxification of sugar streams before fermentation
- Successful fermentation at high solids loading (>20% )
• 200 TPD USA based AFEX depot projected to have $50 - $100/metric ton cost advantage, depending upon raw biomass cost
AFEX Path to Commercialization

- Commercialization will require:
  - Validation of scale-up and economics through design, construction & operation of 100 TPD depot
  - Large scale animal and biorefinery trials
- MBI objectives: 1) Complete derisking at 100 TPD scale, 2) maximize societal benefit through non-exclusive, readily accessible licenses
- MBI Strategy: seek government and philanthropic support in order to retain opportunity to license broadly and inexpensively

AFEX depot CAD drawing by Corrie Nichol, INL
Thank-you for your time and interest

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Successful Scale-up Attracts High-level Interest

President Obama and U.S. Agriculture Secretary Vilsack visit MBI Feb 7, 2014