Conversion of Thin Stillage from Corn-to-Ethanol Dry Mills into Biogas to Offset Natural Gas Consumption

Biofuels and Bioproducts Section

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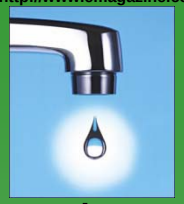
March 7, 2008

Schematic of conventional dry-grind corn to ethanol production


http://www.emagazine.com

Natural Gas

Distilled Ethanol


http://www.whitehouse.gov

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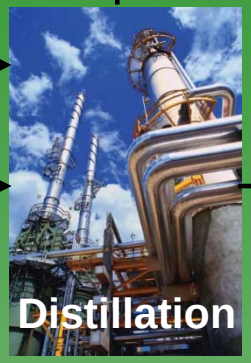


http://eng.nus.edu.sg

Whole Stillage

Thin Stillage Backset

Thin Stillage

http://civil.colorado.edu

Multiple Effect Evaporators

Evaporator Condensate

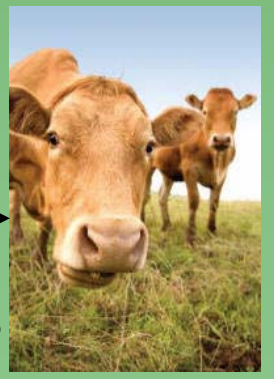
Wet Distillers' Grain

Syrup

Natural Gas

Flash Dryer

Distillers' Dried Grains with Solubles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Thermophilic (55 °C) Anaerobic Digestion of Thin Stillage

Total Chemical Oxygen Demand	**~70-100 g TCOD / l**
Volatile Solids	**~30-90 g / l**
Total Solids	**~35-90 g / l (~90% VS)**

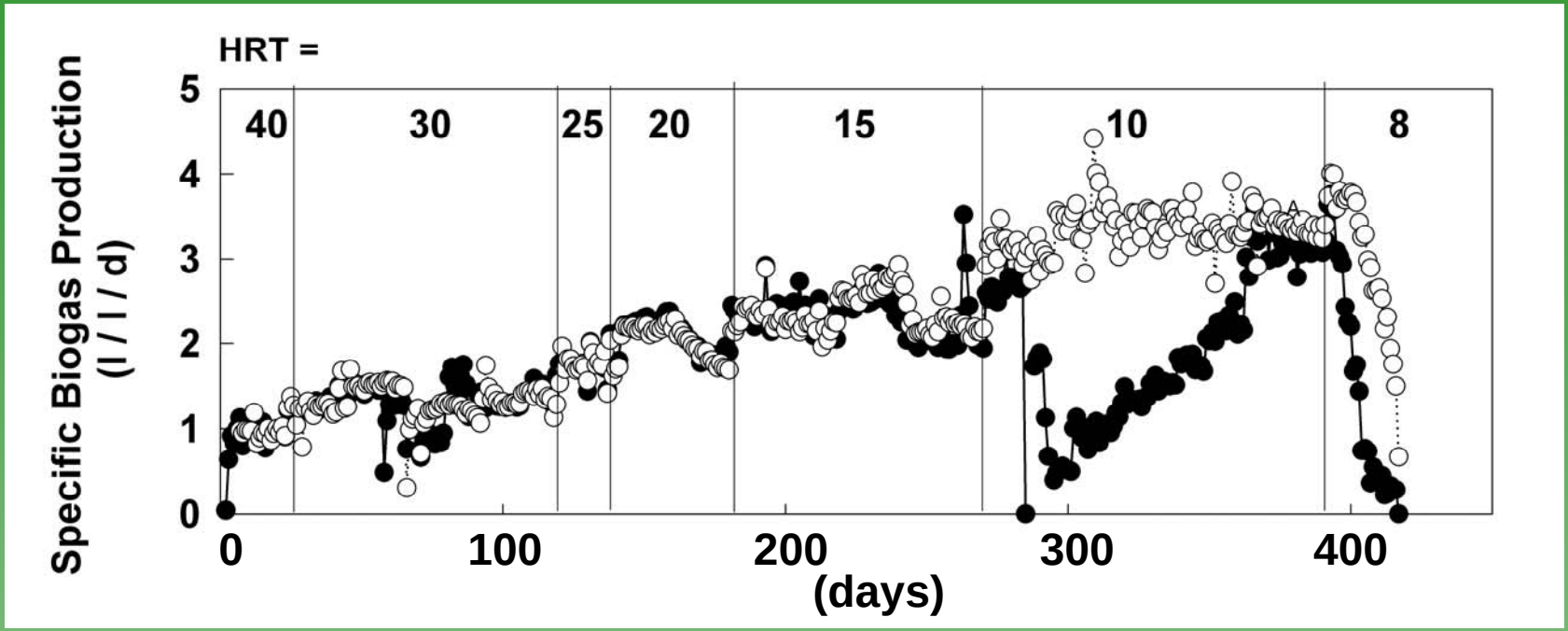
- **Conventional processing requires large amounts of energy**
- **High strength process stream**
- **Solids, which limit recycling, could be mostly removed**
- **Derives from distillation, so thin stillage is already hot**

Corn-to-Ethanol Topic #1

Water Usage

- **Much of requirement due to corn growing**
- **Processing water requirement**
  - **Water recycle from evaporation**
  - **Water loss by flash drying**

Thermophilic (55 °C) anaerobic digestion in two identical 5-L Anaerobic Sequencing Batch Reactors (ASBRs)



- Maximum Stable 10-day HRT (7.50 g TCOD / l / d)
- High volatile solids and TCOD reductions (89% and 92%, respectively)
- Release of ammonia from proteins during solids destruction
- Requirement for trace element to maintain microbial balance

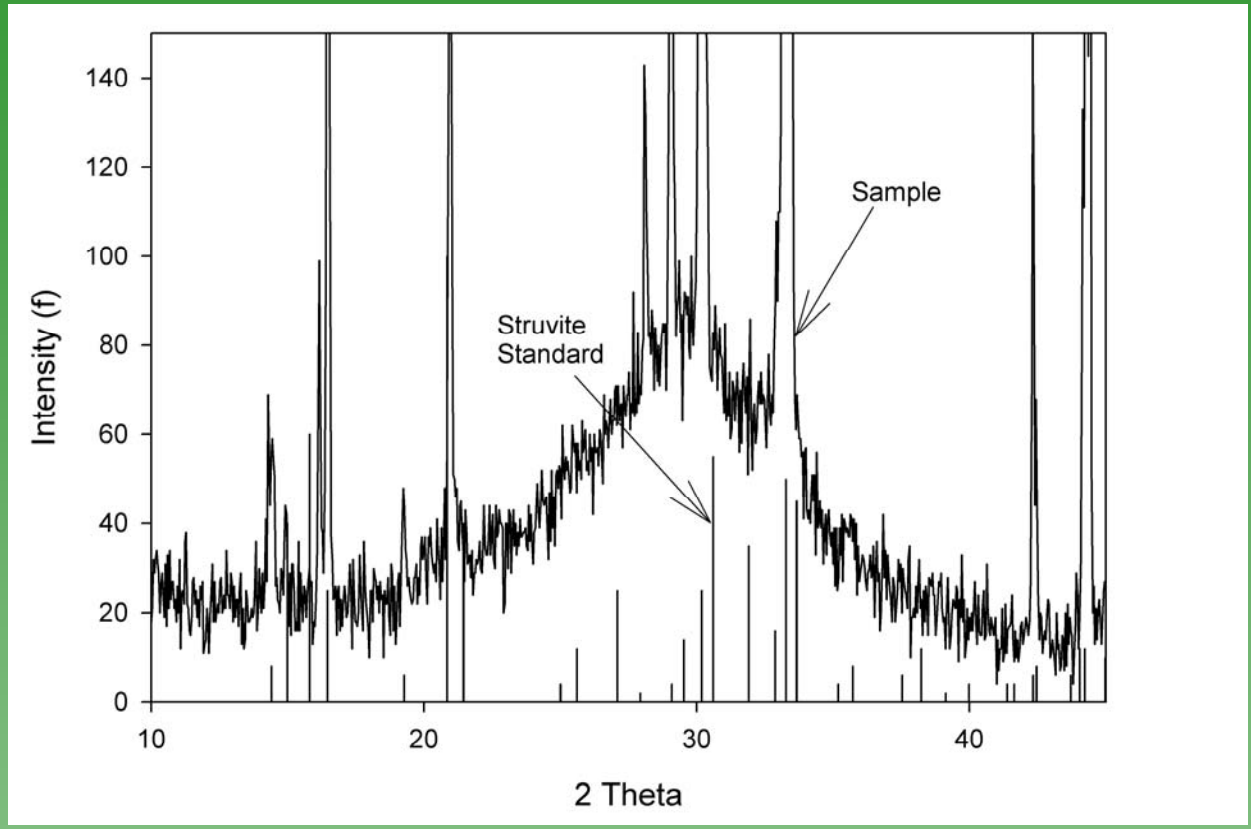
ICP-MS Analysis

Element	Thin Stillage (mg / l)	R1 Effluent (mg / l)	R2 Effluent (mg / l)
Co	<DL	2.71	2.77
Mg	$3.7x10^2$	$1.66x10^1$	$1.40x10^1$
P	$4.14x10^3$	$3.37x10^2$	$3.53x10^2$

Cobalt is important for:

- **Methyl transfer enzymes for methanogenesis**
- **Important for some bacteria**

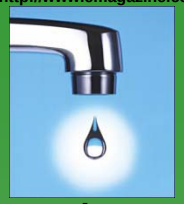
Precipitate Analysis



- Mg and P are removed in significant amounts via struvite [$(NH_4)Mg(PO_4)$] Formation
- Mg is the limiting factor
- Precipitate contains only 0.286 moles N per mole precipitate

Schematic of improved dry grind corn-to-ethanol production


http://www.whitehouse.gov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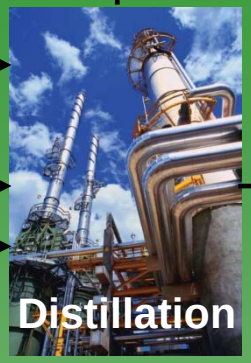
Distilled Ethanol



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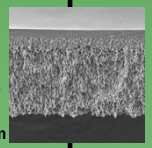
Whole Stillage

Membrane Technology


http://www.millipore.com

Biogas

Thin Stillage

http://civil.colorado.edu

Anaerobic Digestion

Digester Effluent

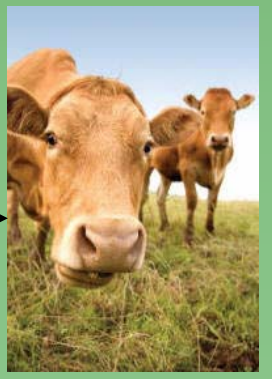
Wet Distillers' Grain

Biogas

Natural Gas

Flash Dryer

Distillers' Dried Grains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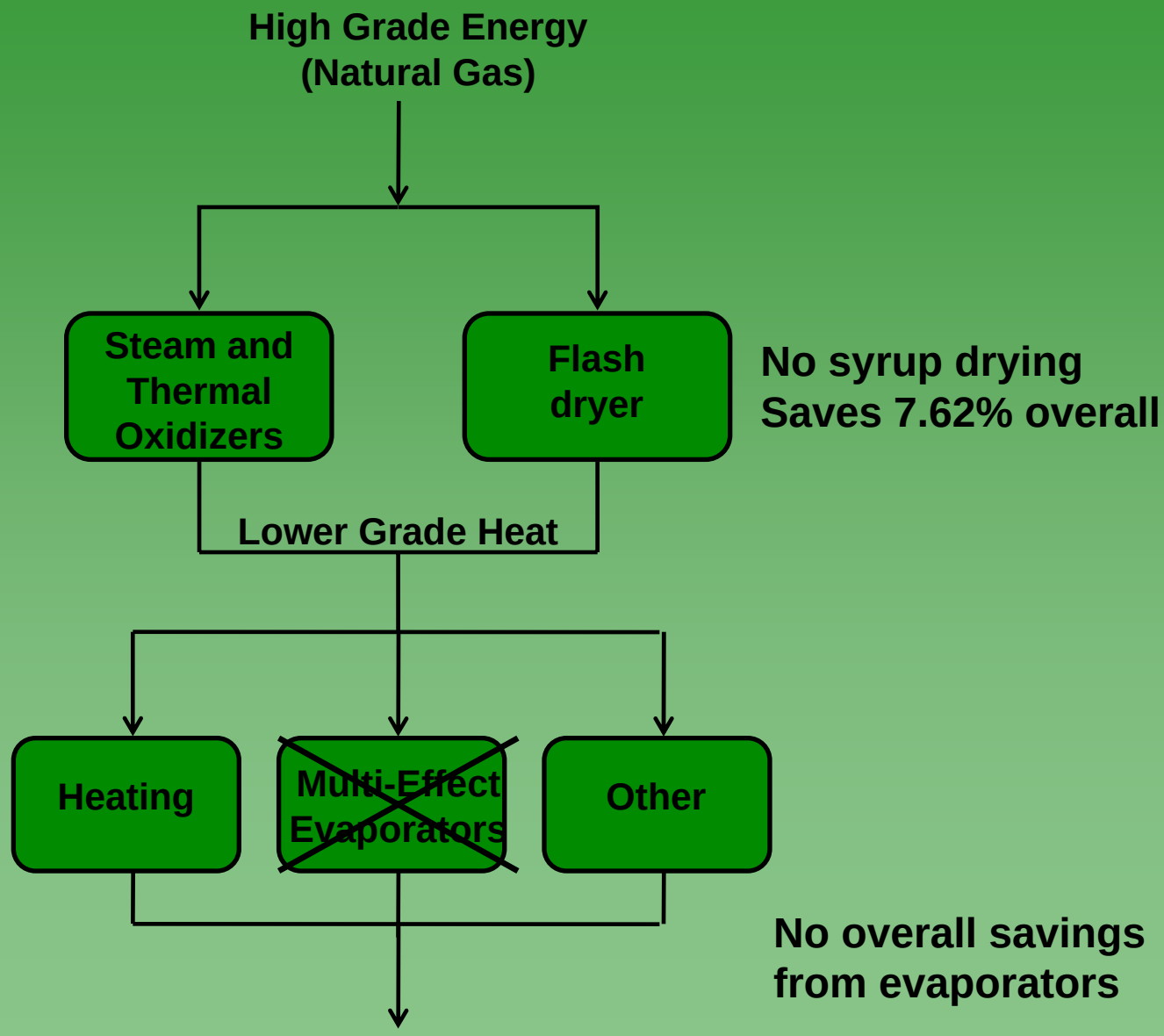
Corn-to-Ethanol Topic #2

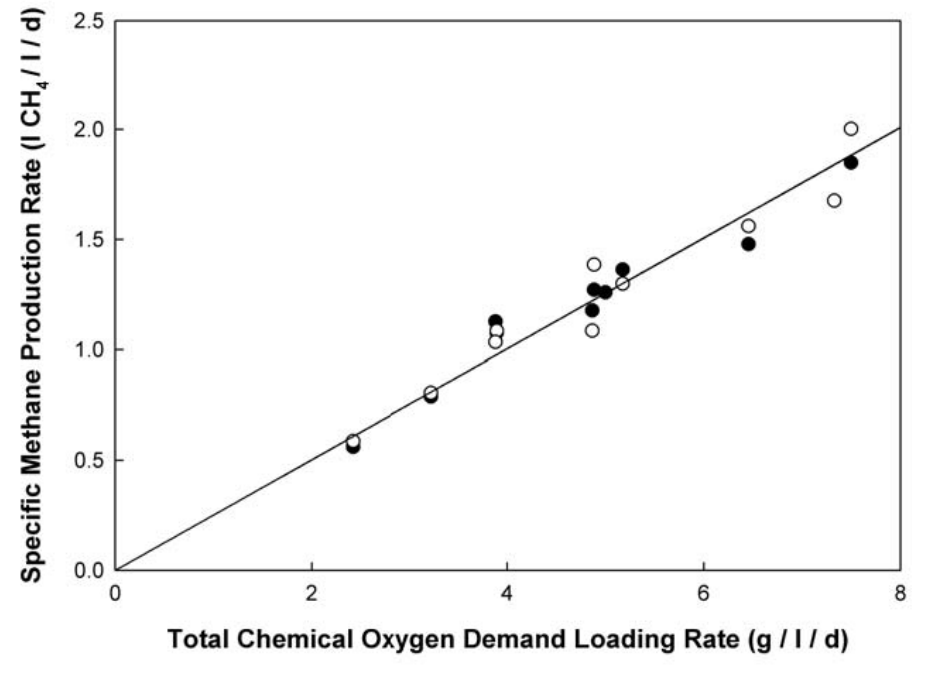
- Energy (1.26 Net Energy Balance Ratio*)
  - Farm ← **31.3% of energy inputs***
  - Processing ← **62.5% of energy inputs***
    - **A good place to look for improvements**
    - **Conventional thin stillage treatment *uses* energy**

Hill et al., 2006, *Proceedings of the National Academy of Sciences

Energy Cascade



Anaerobic digestion produces energy in the form of biogas (methane)



Agler et al., submitted

Methane Yield

Combined yield from the two reactors digesting thin stillage (R^2 = 0.99):

0.254 l CH_4 / g TCOD

Methane: 35.87 kJ / l CH_4

Energy Savings Calculations

Calculations for a 3.78×10^8 l ethanol / yr full-scale dry mill

- **0.958 original total energy input (per unit energy in ethanol)***
  - **0.599 from processing inputs***
  - **50.56% reduction, reduces processing energy input to 0.296**
  - **0.655 new total energy input**
- **1.203 original total energy output (per unit energy in ethanol)***
  - **0.203 from animal feed credit (DDGS)***
  - **45.19% feed mass reduction**
  - **1.11 new total energy output**
- **New net energy balance ratio is 1.70**

Hill et al., 2006, *Proceedings of the National Academy of Sciences

Summary

Corn grain ethanol production is a stepping stone to better, more efficient technology

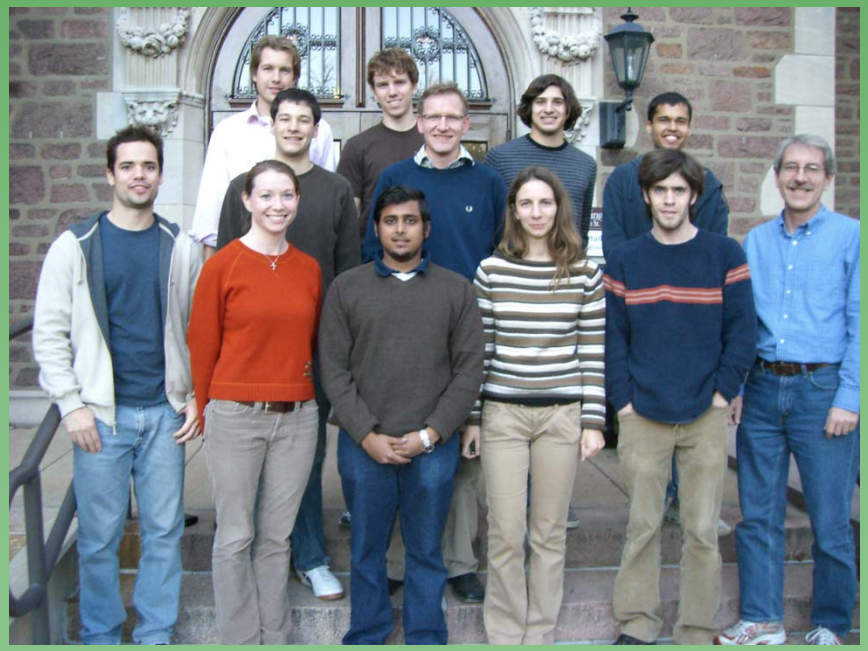
Recovery of Digester Effluent

- **Reduced solids, organics, and some metals**
- **Nitrogen released in the form of ammonia**
- **Struvite precipitation**
- **Membrane filtration possibly still required**

Energy Improvements

- **High biogas production rate with stable operation**
- **Reduced amounts of animal feed**
- **NEB ratio improvement 1.26→1.70**

Acknowledgments



- IDCEO
- NCERC
- Angenent Lab

Questions?