Pre-Treatment Technologies for Increasing the Biogas Potential of Agricultural Wastes

Tim Shepherd
CE 521
30 November 2006

IOWA STATE UNIVERSITY
Agricultural and Biosystems Engineering

Introduction of AD

- Widely Used in Municipal Systems
  - Fewer Applications in Agriculture

- Microbes Consume Substrate Producing CH_4 and CO_2
  - Stabilizes and Reduces Solids
  - Conserves Nutrients
  - Produces Renewable Energy
  - Controls Odors

AD Limitations in Agriculture

- Compared to Traditional Manure Systems
  - High Capital Investment
  - Maintenance and Operation
  - Limited Economic Return
  - Safety Concerns

- Economical Solids Loading ~ 5%
  - Ag Waste Total Solids 2% - 10%

Pretreatment Technologies

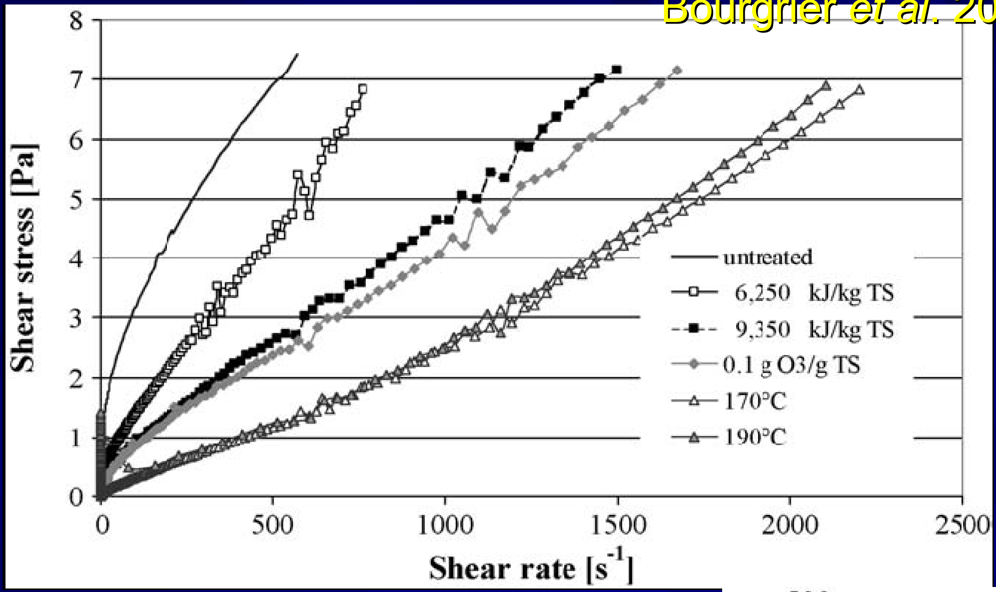
- Maceration
  - Chopping, Grinding, Blending, ect.
  - Reduce Particle Size, Break Fibers
- Chemical Treatment
  - Addition of Caustics (NaOH, NH_4OH, H_2SO_4)
  - Destruction of Lignin Bonds
- Liquefaction
  - Forced Explosion of Cellular Structure
  - Disassociation of Fibers and Colloids

Pretreatment Technologies

- Thermal Hydrolysis
  - Heating: 100-200^{o}C for 30-120 minutes
  - Disrupts Cells, Destroys Lignin Bonds
- Sonication
  - Low Frequency Ultrasound Waves
  - Cell Lysis, Solids Solubilization
- Ozonation
  - Oxidation of Organic Matter
- Biological
  - Aerobic Digestion
  - Cellulose and Hemicellulose Degrading Bacteria

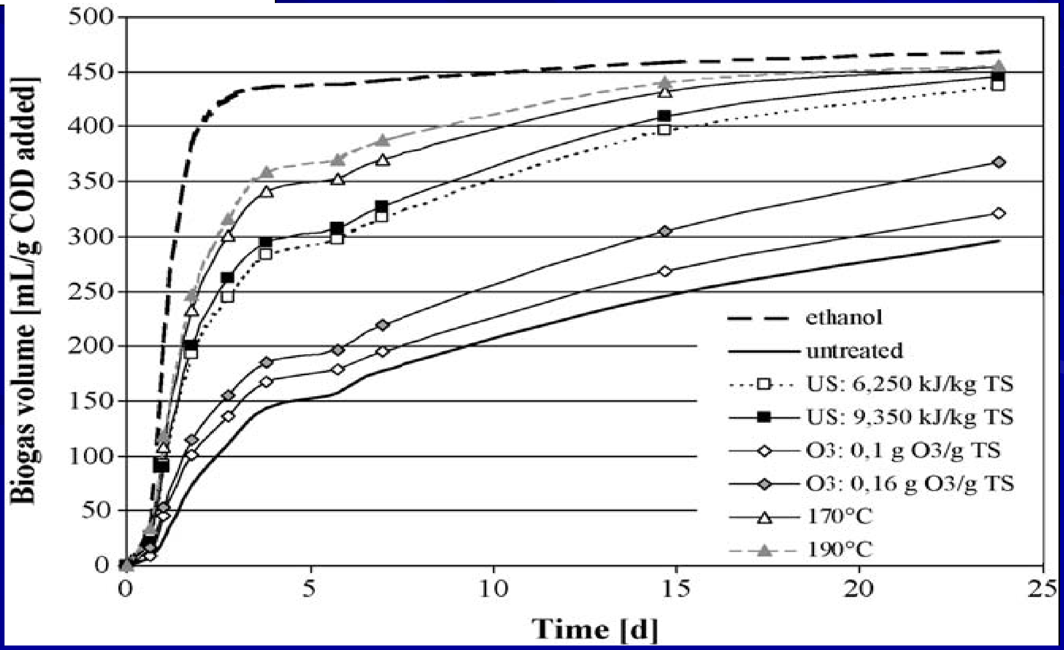
Case Study 1

Bourgrier *et al.* 2006a



- Non-Newtonian Liquid
- Treatment Provides
  - Shift Towards Newtonian Fluids
  - Reduced Apparent Viscosity

- Increased Biogas Production
- Increased Production Rate
- Thermal and Sonication Provide Best Results



Case Study 2

Ardic and Taner 2005

Thermal vs. Chemical vs. Thermochemical

- Increases Solubility of Organics
  - All Treatments
- Reduced Particle Size
  - Thermal and Thermochemical
- Increased Biogas Production
  - Thermal
- Methanogenic Inhibition
  - High Dose Chemical Treatments

Case Study 3

Angelidaki and Ahring 2000

Maceration vs. Liquefaction vs. Chemical vs. Biological

Treatment		CH_4 potential increase (%)
Maceration	< 0.35 mm	20
Maceration	2 mm	16
Decompression explosion		17
NaOH	20 g/kg VS	13
NaOH	40 g/kg VS	23
NH_4OH	<20 g/kg VS	0
NH_4OH	40 g/kg VS	23
$NaOH:KOH:Ca(OH)_2$	40 g/kg VS	20
Hemicellulose degrading bacterium B4		30

Case Study 4

Valo *et al.* 2000; Bourgrier *et al.* 2006b

Chemical vs. Thermochemical

- Two Waste Sources
- Semi-Continuous System

Methane Yield, L/kgVS				
Sludge	Raw	130^{o}C, KOH	150^{o}C	170^{o}C
1	128 +/- 5	220 +/- 4		228 +/- 5
2	145 +/- 5		238 +/- 4	256 +/- 7

Full Scale Applications

Municipal Systems Most Common

- Prague → Maceration
  - 7.5% Increased Biogas Production
  - Supports Energy Demand

- UK, Sweden, USA, Australia → Sonication
  - Improved Solids Destruction
  - Substantial Increase in Biogas Production
  - Enhanced Dewatering
  - Reduced Sludge Production
  - 2-Year Payback Period

Full Scale Applications

Muhler *et al.* 2004

Maceration vs. Sonication vs. Ozonation

- Economic Assessment
  - Increased Solubilization
  - Improved AD Performance
  - Economic Viability Dependant upon Sludge Disposal Costs

Agricultural Applicability

- Maceration
  - Simple System Operation
  - High Maintenance and Operating Costs
- Liquefaction
  - Complex System
  - High Capital Investment
  - Safety with High Pressure System

Agricultural Applicability

- Chemical
  - Simple Application
  - High Chemical Costs / Low Capital Cost
  - Safety Concerns with Storage and Handling of Caustics
- Ozonation
  - Simple Application
  - Moderate Operating and Capital Cost
  - Least Effective Method

Agricultural Applicability

- Thermal
  - Flexible System
  - Capital Costs are Minimal
  - Energy Economics are Critical
- Sonication
  - New Technology
  - High Capital Costs

Agricultural Applicability

- Biological
  - With Proper Management
    - Low Energy Consumption
    - Low Maintenance
    - Limited Capital Expenditures
  - Technological Advancements
    - Enhanced Performance and Reliability
    - Unrealized Potential

Conclusion

- Pretreatment Enhances AD
- Provides Benefits in Ag Systems
- Full Potential Realized with Economic Benefits
- Thermal, Sonication, and Biological are Most Feasible Pretreatment Systems

Questions?