"Ultrasound Pretreatment of Corn Slurry for Enhanced Saccharification"

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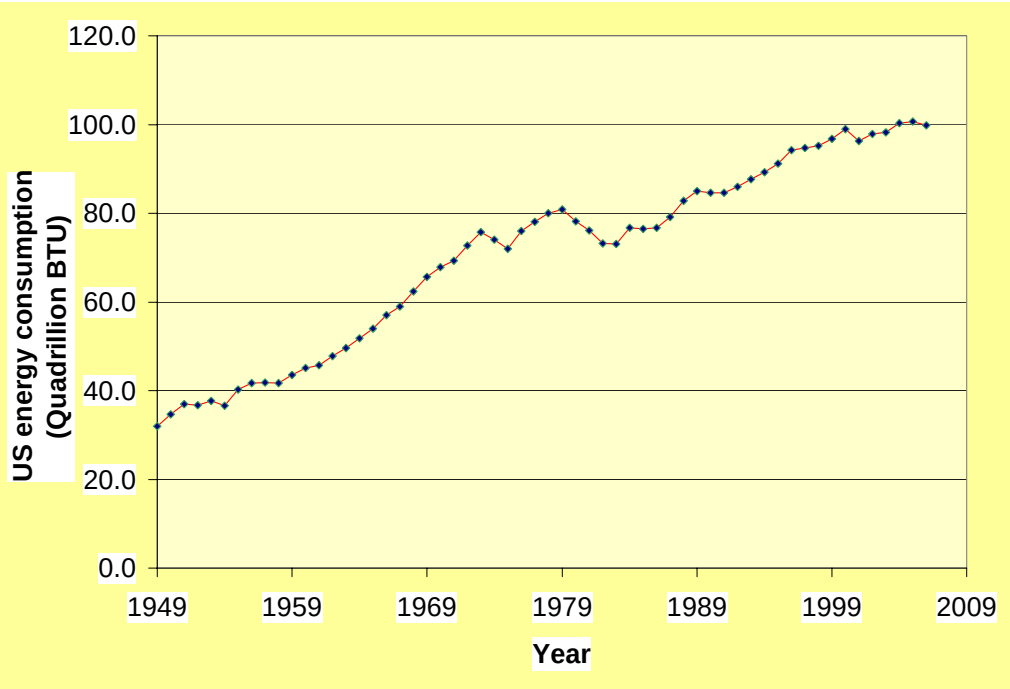
INTRODUCTION

- **U.S. Annual energy consumption has reached 100 Quadrillion BTU in 2005**
- **28% energy consumption comes from the transportation sector**



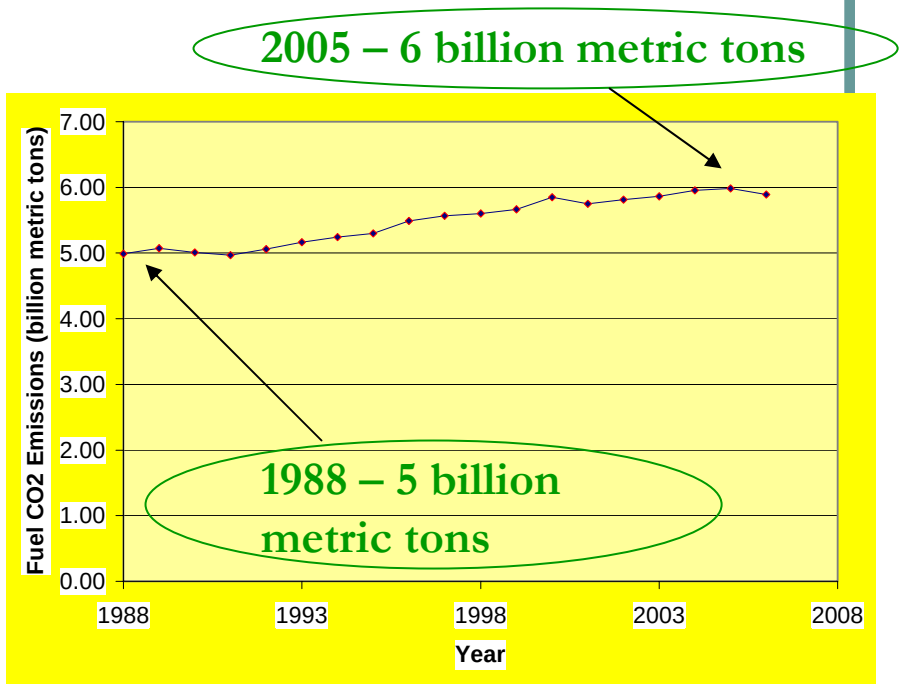
Reference: U.S. Energy Information Administration.
Also available at http://www.eia.doe.gov/

INTRODUCTION

Current Issues on Petroleum:

- Dependence on foreign oil
- Threat to national security
- Gasoline prices continued to increase
- Increasing Greenhouse gas emissions

Year	Gasoline ($/Gallon)
1993	1.07
2000	1.52
2003	1.60
2006	2.61
2007	2.84
Feb 2008	3.08



Reference: U.S. Energy Information Administration.
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BIORENEWABLE ENERGY

- **Stronger demand for renewable fuel**
- **Ethanol and Biodiesel are among the leading biorenewable energy used**

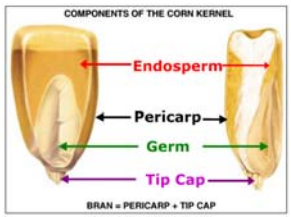
Net Energy Value (NEV) is defined as the energy content of ethanol minus the fossil energy used to produce ethanol.

	NEB (Btu per gallon)	Output to input ratio
Pessimistic Approach[1]	-22,119	0.78
Optimistic Approach[2]	+21,105	1.34

[1]Pimentel D. Natural Resources Research 12:127-134, 2003.

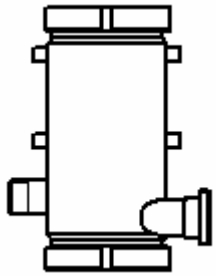
[2]Shapouri H., Duffield J., and Wang D. USDA, agricultural economic report number 814, 2002.

DRY GRIND MILLING



1

Corn slurry



2

Jet cooker

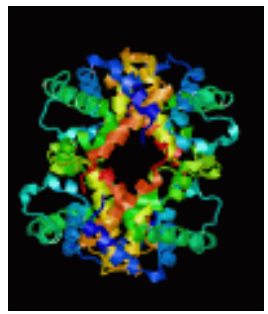
Liquefaction tank

- **Recent technologies in ethanol production**
- **Ultrasonics, a potential pretreatment**
- **Dry milling plant requires 37,000 Btu[3] thermal energy per gallon ethanol produced**
- Ultrasonics in Dry Grind Milling Animation

[1]Cereal process technologies website, www.cerealprocess.com/fractionation.htm [2]GMFgouda website, www.gmfgouda.com/jet-cooker/jet-cooker.html [3]Shapouri H., Duffield J., and Wang D. USDA, agricultural economic report number 814, 2002.

RESEARCH OBJECTIVES

- Investigate the efficiency of a batch lab-scale ultrasonic system in disintegrating corn particles



- Determine the efficiency of ultrasonics as liquefaction pretreatment method

- Study the effects of ultrasound on enzyme

MATERIALS

Ultrasonics

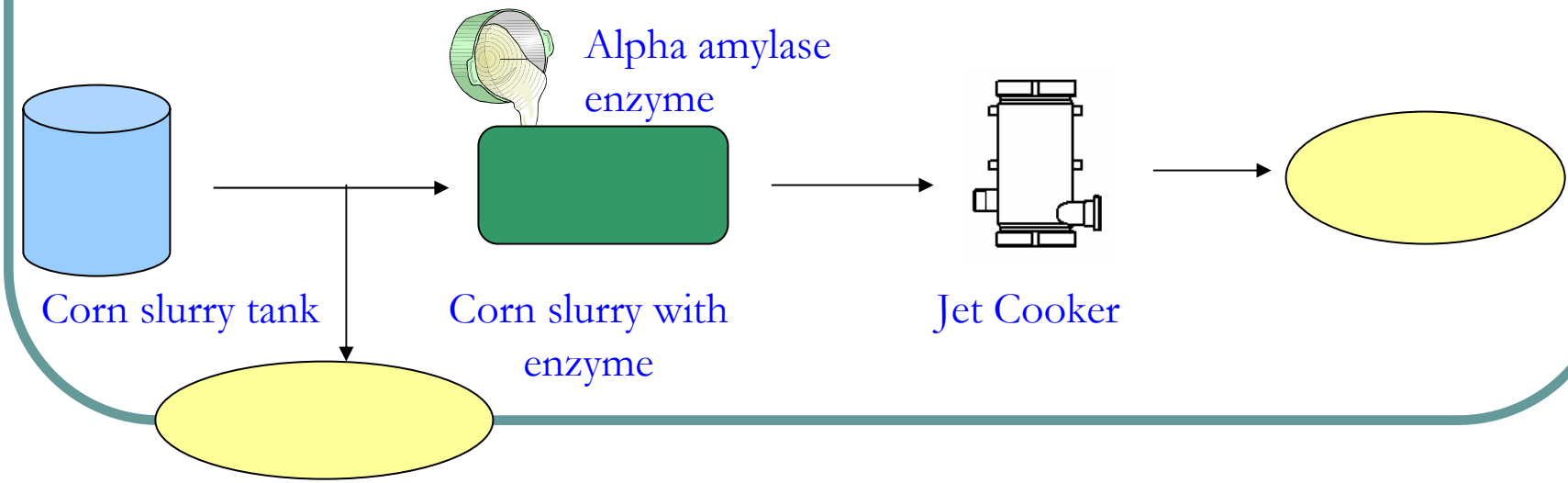
- Branson Ultrasonics 2000 series unit
- Output 2.2 kW & 20kHz

Enzyme

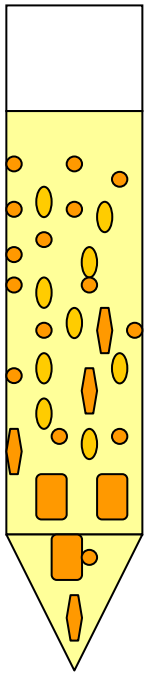
- STARGEN 001 (Genencor International)

CORN

- Dry ground corn (Lincolnway Energy)
- Corn Slurry (Midwest Grain Processors)



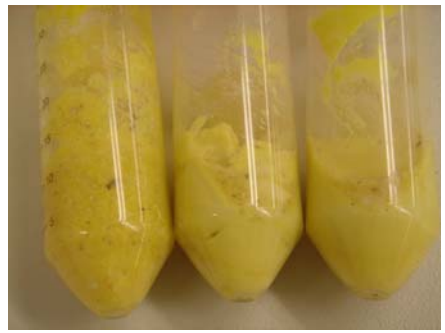
BATCH EXPERIMENTS



Corn slurry; acetate buffer pH 4.3

Liquefaction & Saccharification for 3 hours at 32°C

After centrifugation; Reducing sugar analysis is conducted

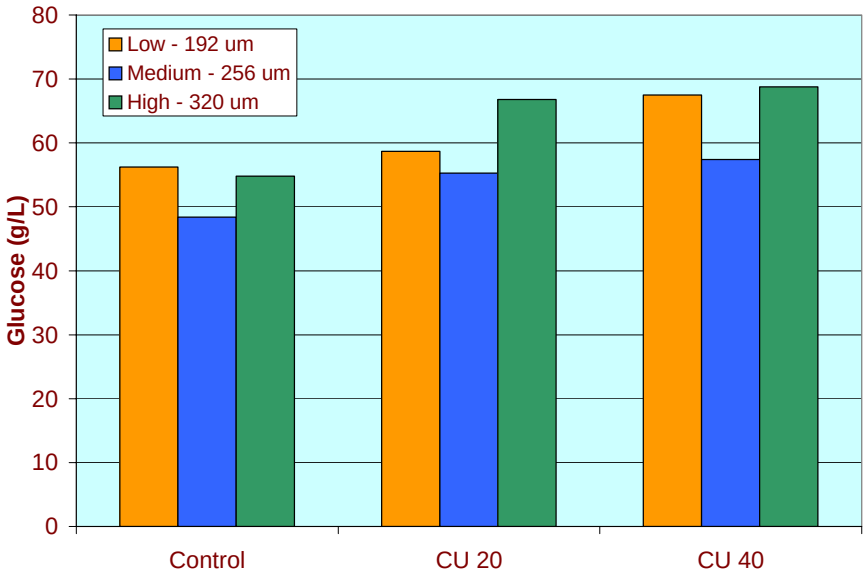


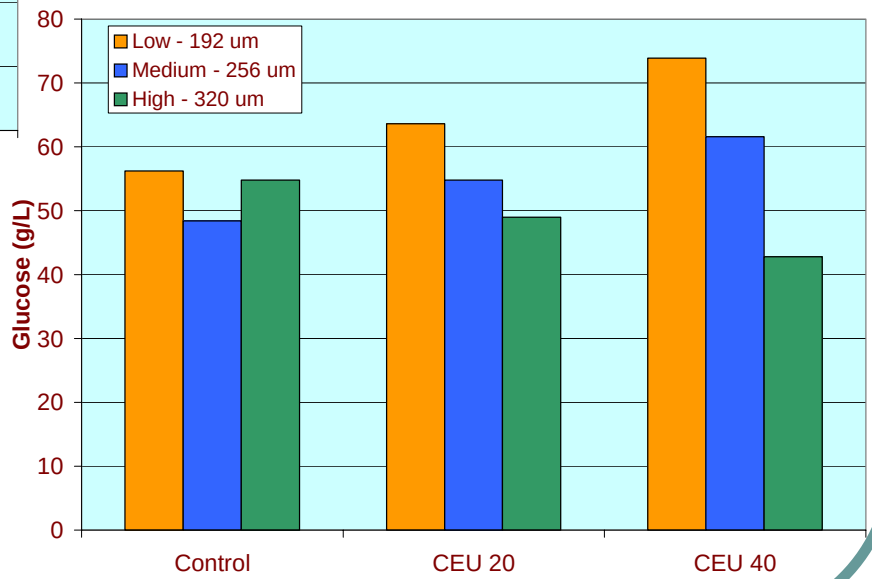
All experiments will be conducted in duplicate and analysis in triplicate

EXPERIMENTAL CONDITIONS

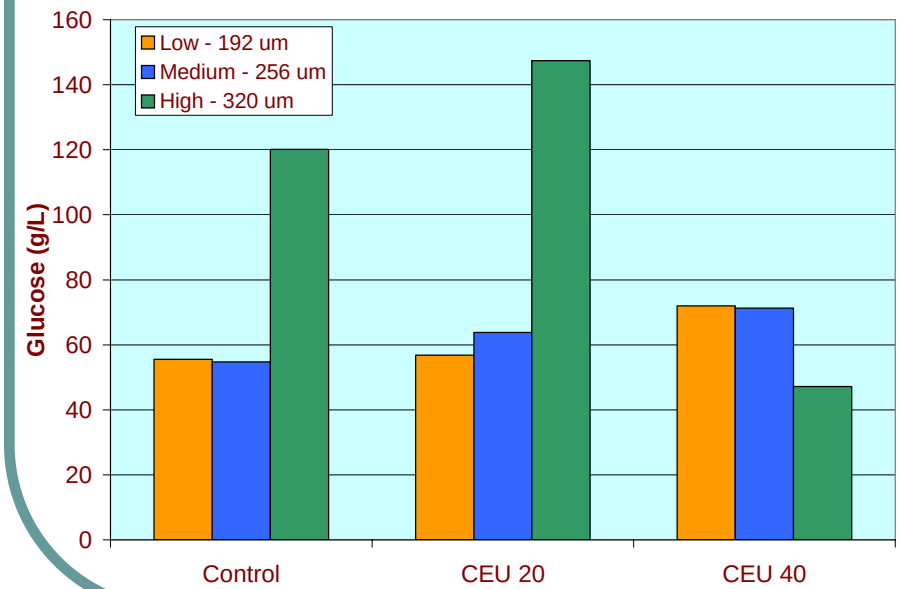
Sample Nomenclatures	Power Inputs (Watts) Amplitude (μm)		Experiments
Control	***0***		***Raw or cooked corn slurry with enzyme***
CU_{20}/CU_{40}	**Low (192 μm)**	**274±5**	**Raw or cooked corn slurry with enzyme addition after sonication for 20 or 40 seconds**
CEU_{20}/CEU_{40}	**Medium (256 μm)**	**350±5**	**Raw or cooked corn slurry with enzyme addition during sonication for 20 or 40 seconds**
	High (320 μm)	**475±15**	

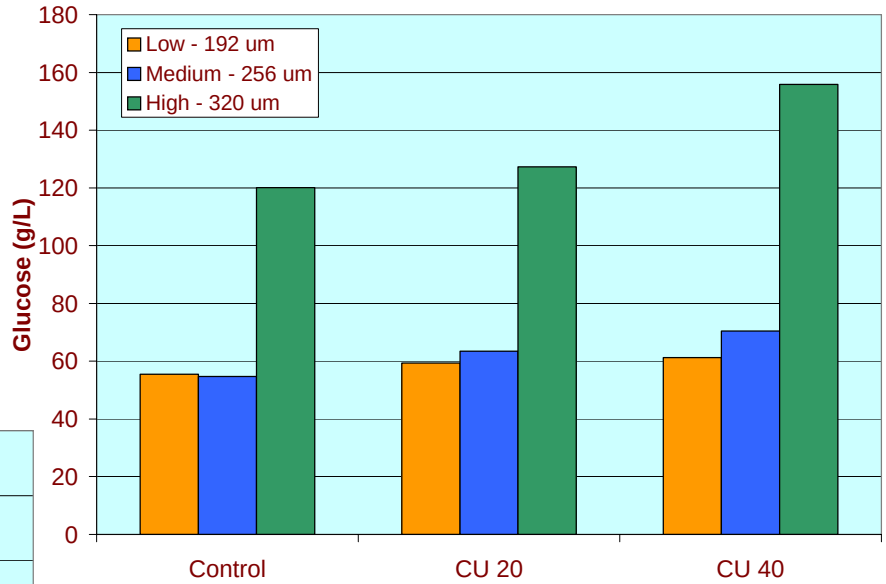
RESULTS
(Glucose Yield – Raw Corn Slurry)



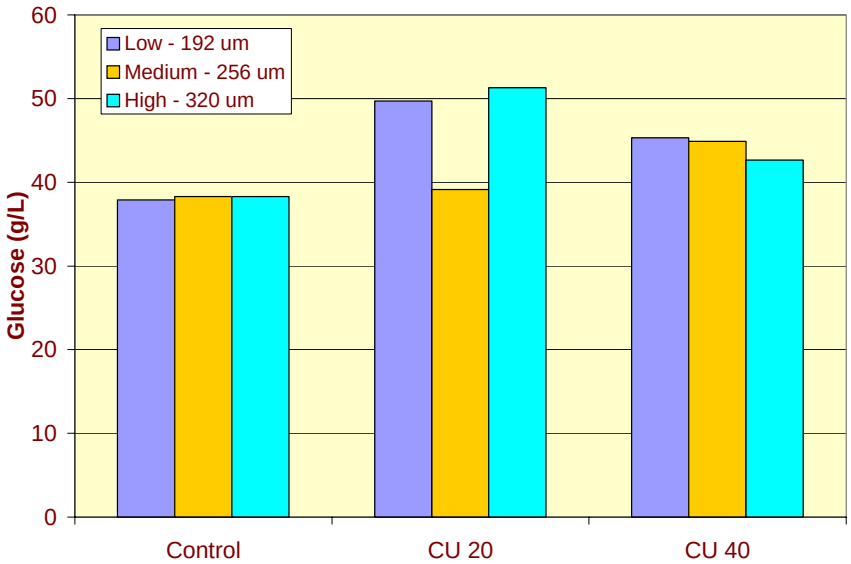


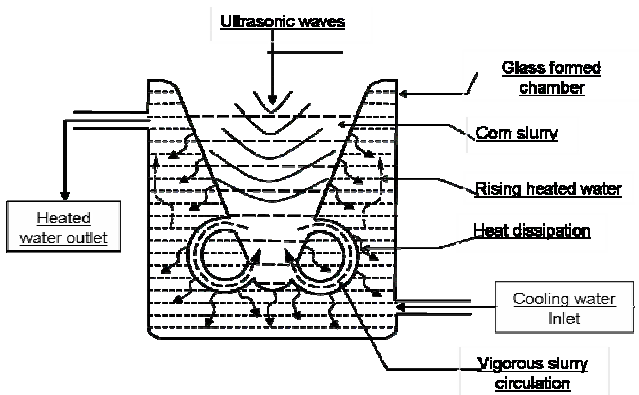
RESULTS
(Glucose Yield – Cooked Corn Slurry)

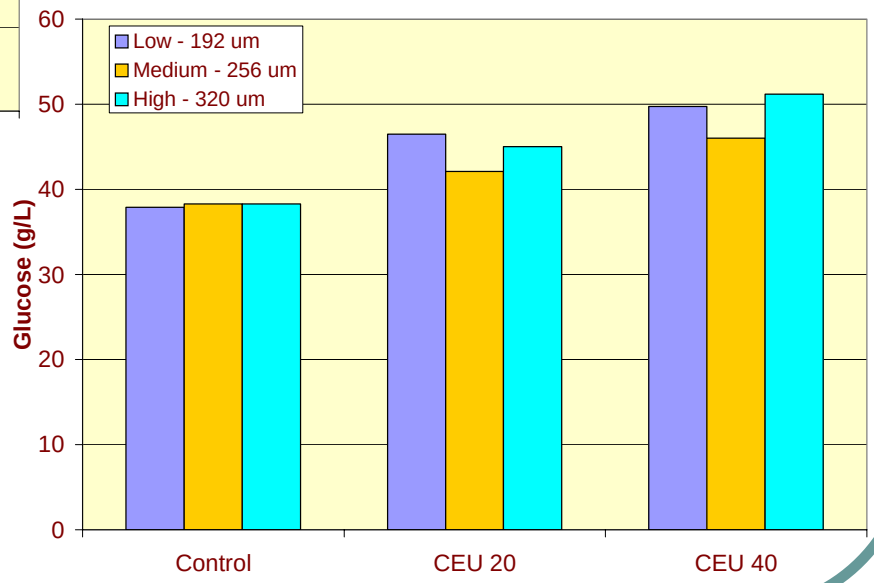




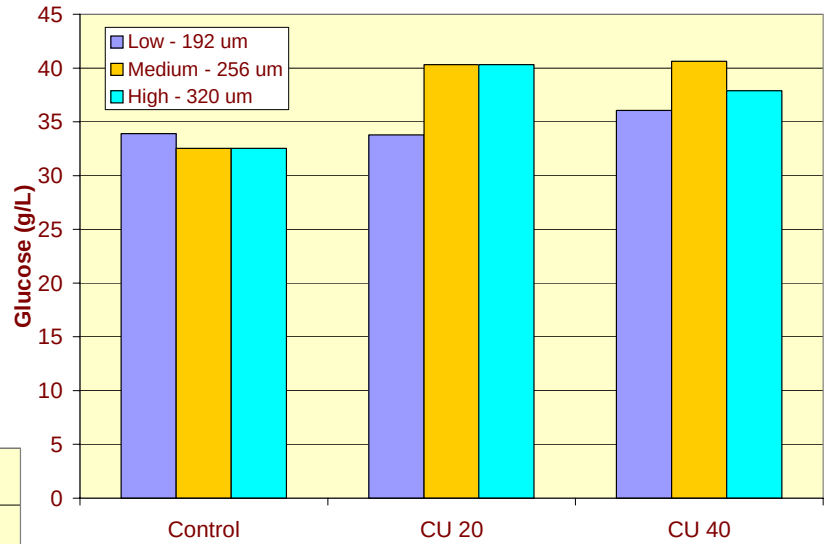
Temperature Controlled Experiments (Glucose Yield –Raw Corn Slurry)

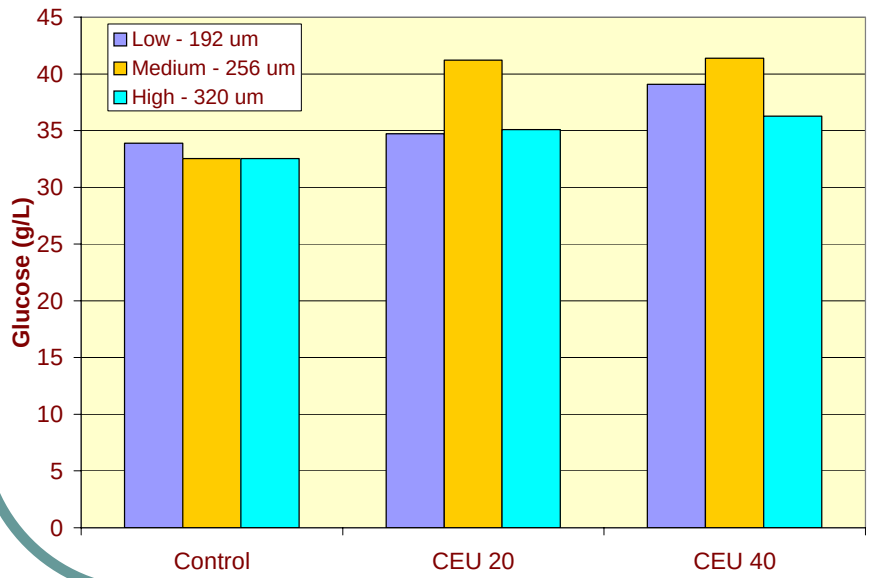




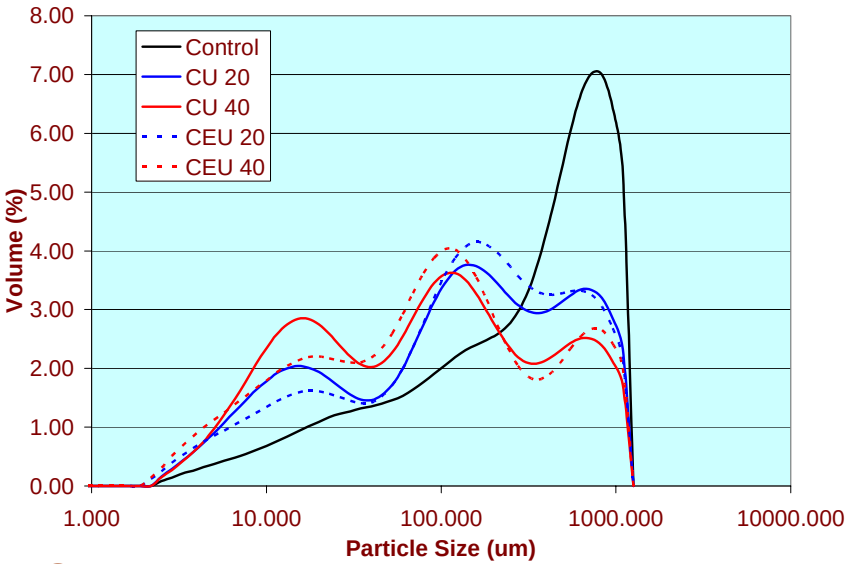


Temperature Controlled Experiments (Glucose Yield – Cooked Corn Slurry)

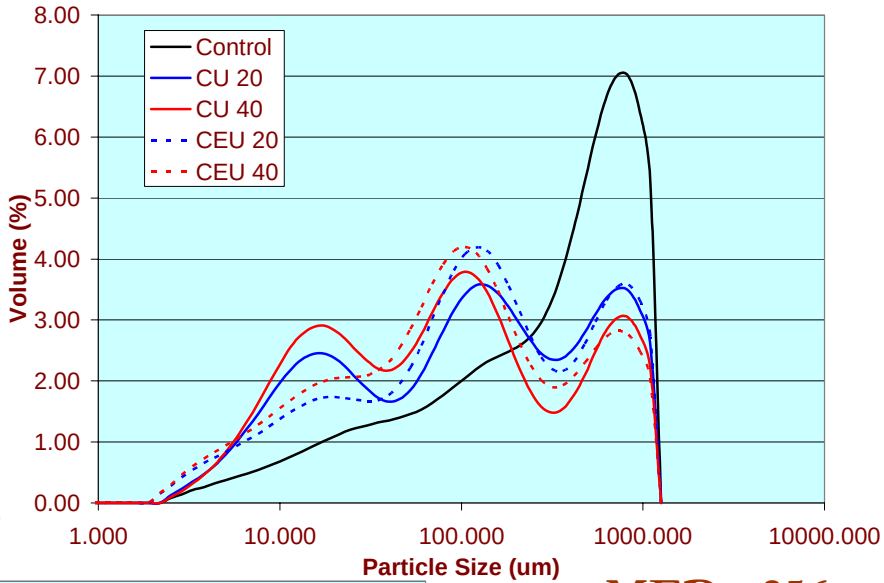




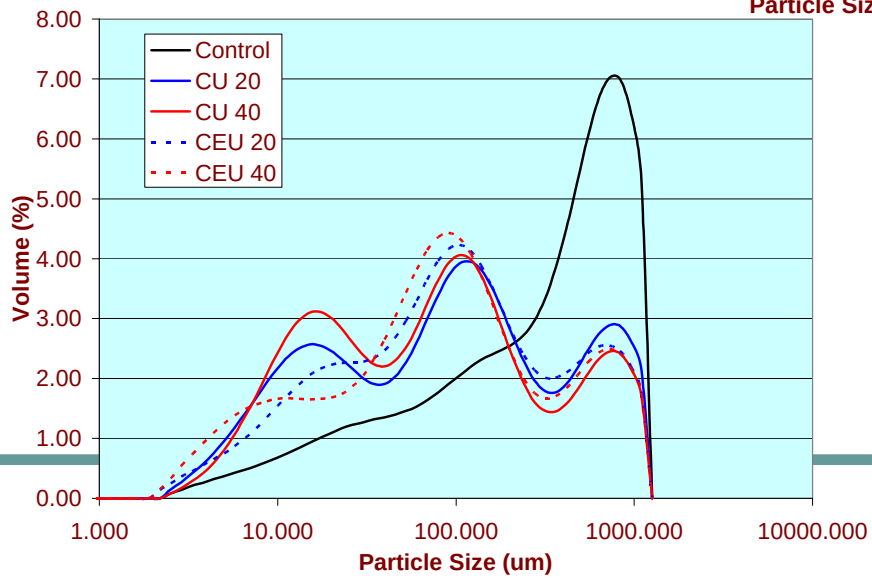
Particle Size (Raw Corn Slurry)



LOW - 192µm

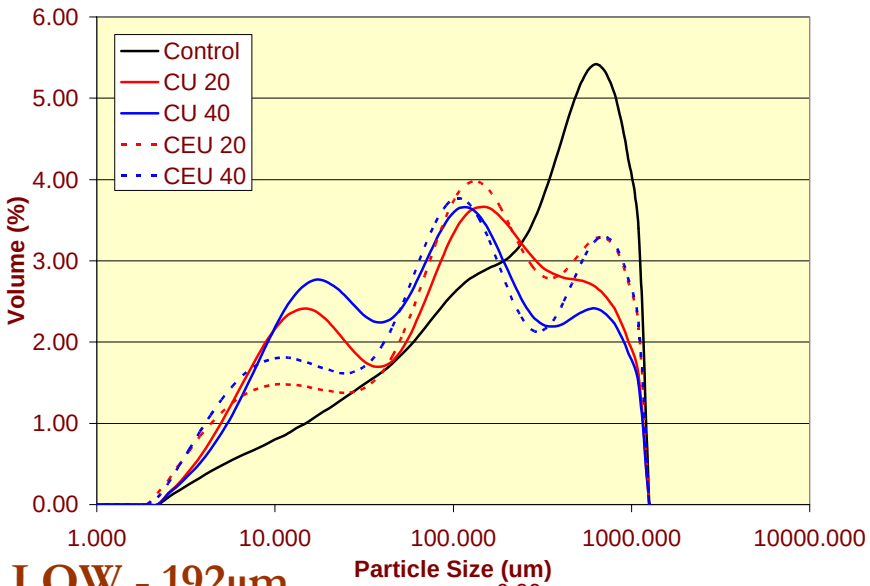


MED - 256µm

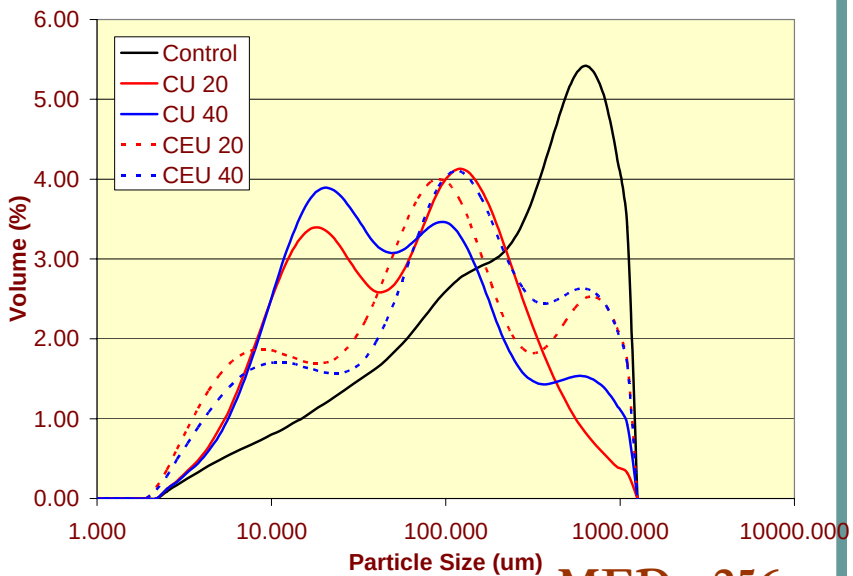


HIGH - 320µm

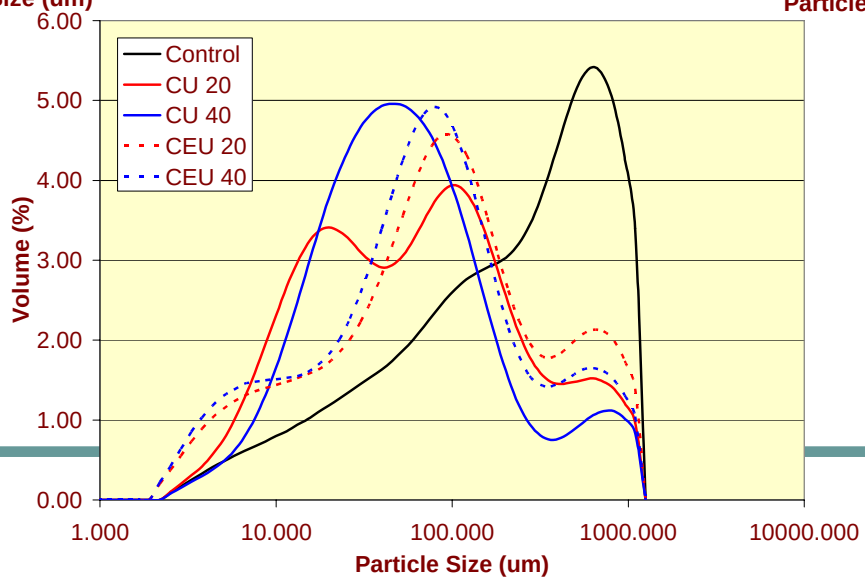
Particle Size (Cooked Corn Slurry)



LOW - 192µm



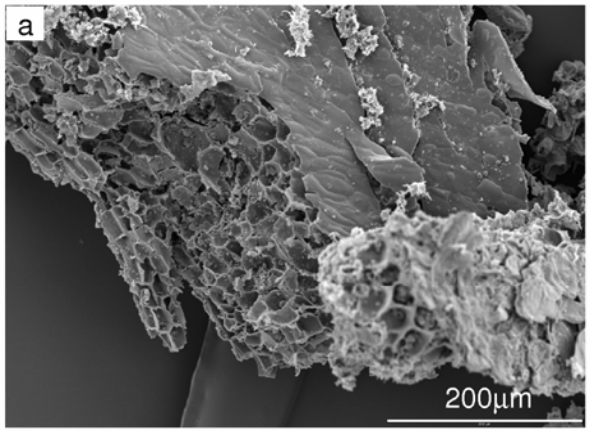
MED - 256µm

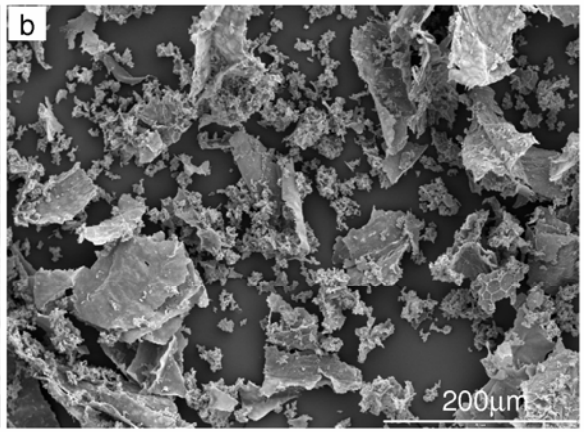


HIGH - 320µm

SCANNING ELECTRON MICROSCOPE (SEM) IMAGES

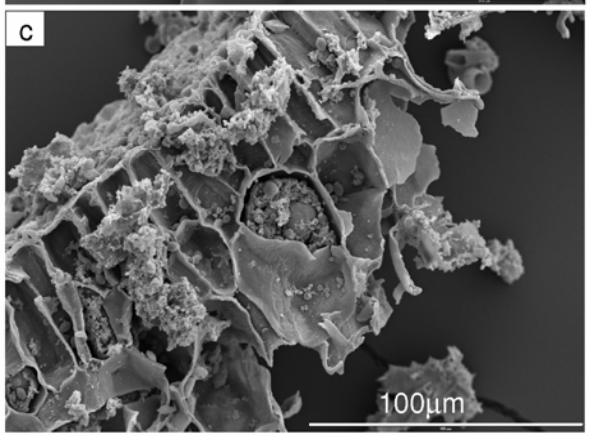
Raw Corn Slurry

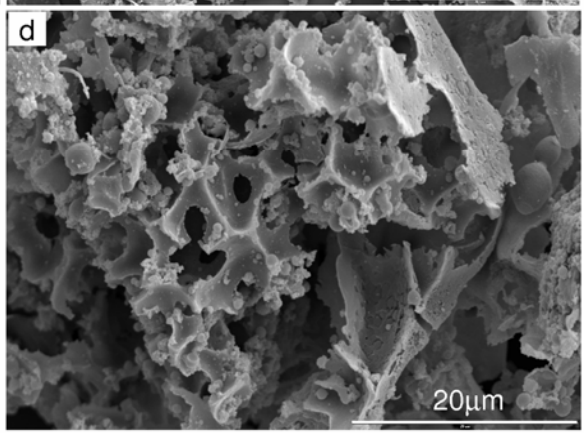




Raw Corn Slurry Sonicated for 40s at 320µm

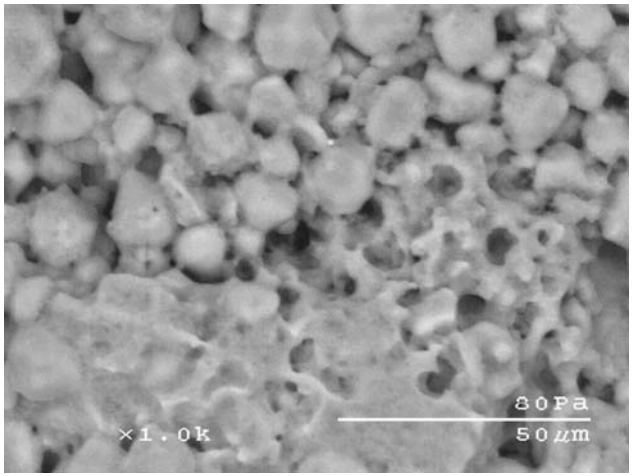
Cooked Corn Slurry



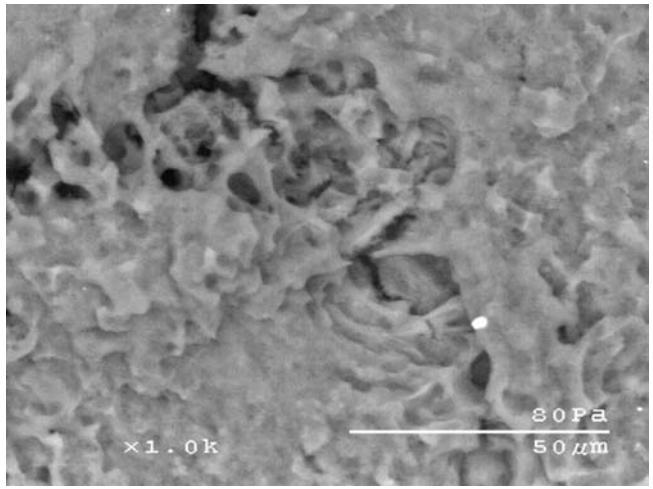


Cooked Corn Slurry Sonicated for 40s at 320µm

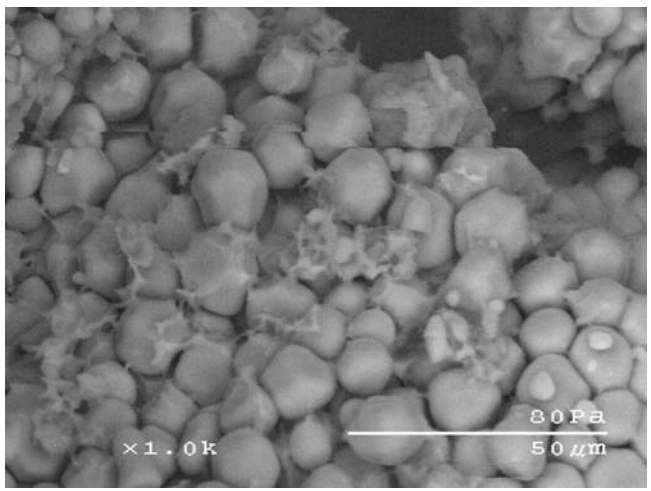
SCANNING ELECTRON MICROSCOPE (SEM) IMAGES



Ground corn unsonicated



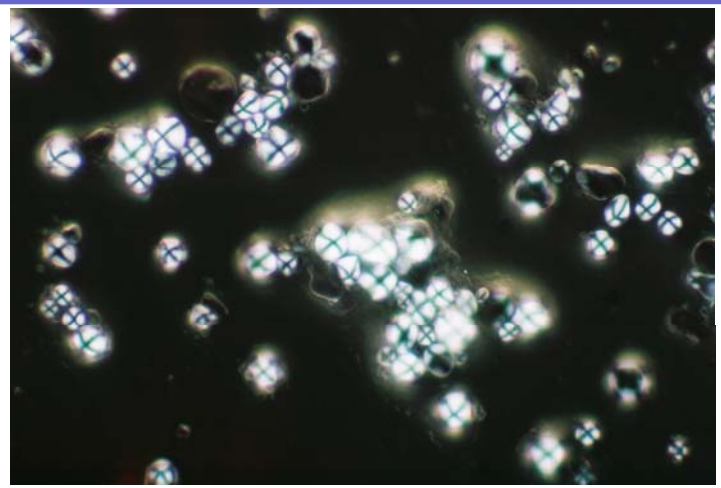
Corn slurry sonicated for 20 seconds at 320μm



Corn slurry sonicated for 40 seconds at 320μm

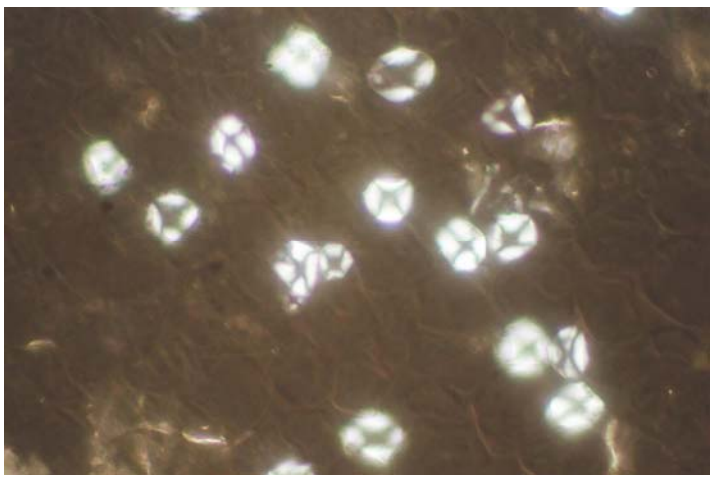
POLARIZED MICROSCOPE IMAGES

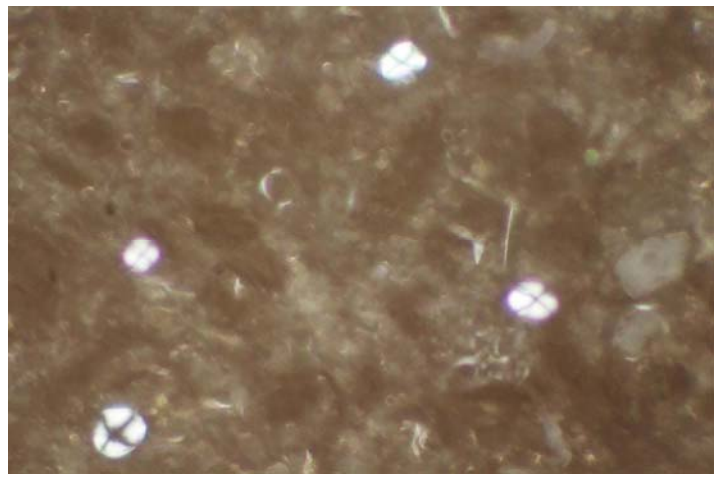
Ground corn sonicated for 30 seconds at 320µm



Ground corn control

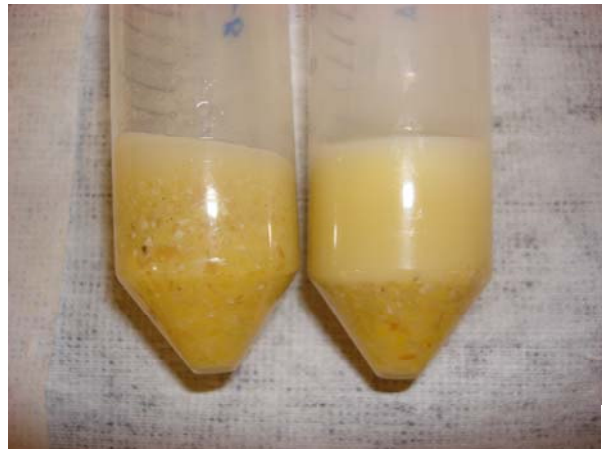
Ground corn sonicated for 40 seconds at 320 µm

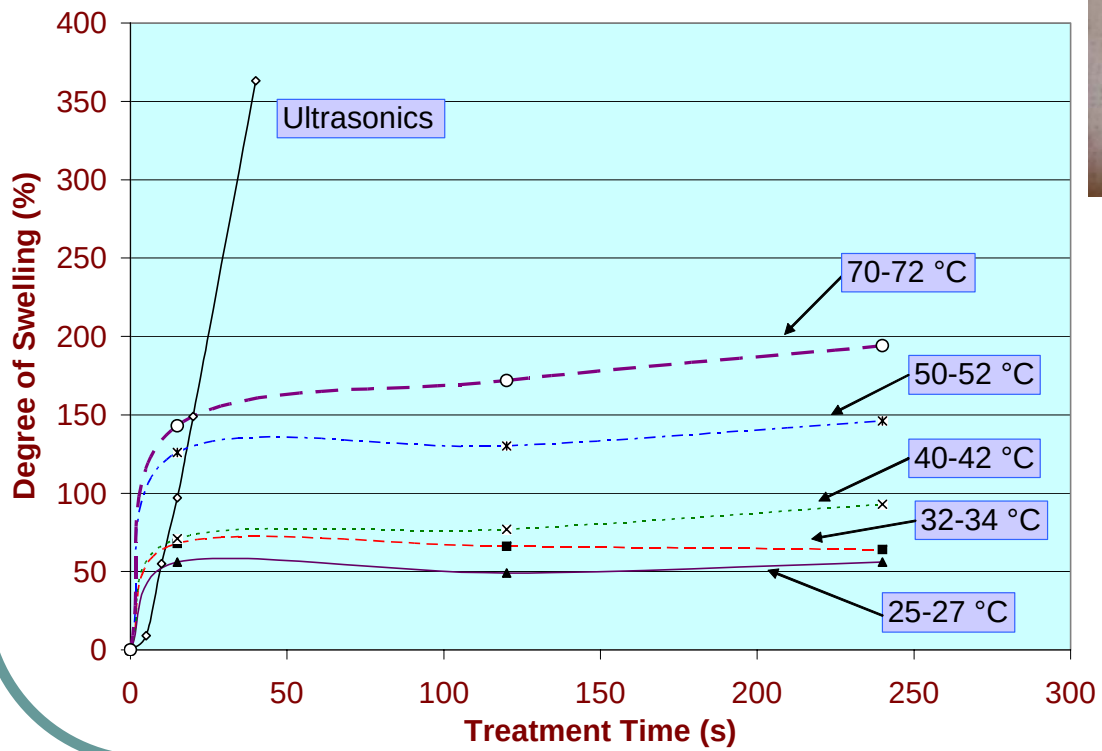




DEGREE OF SWELLING

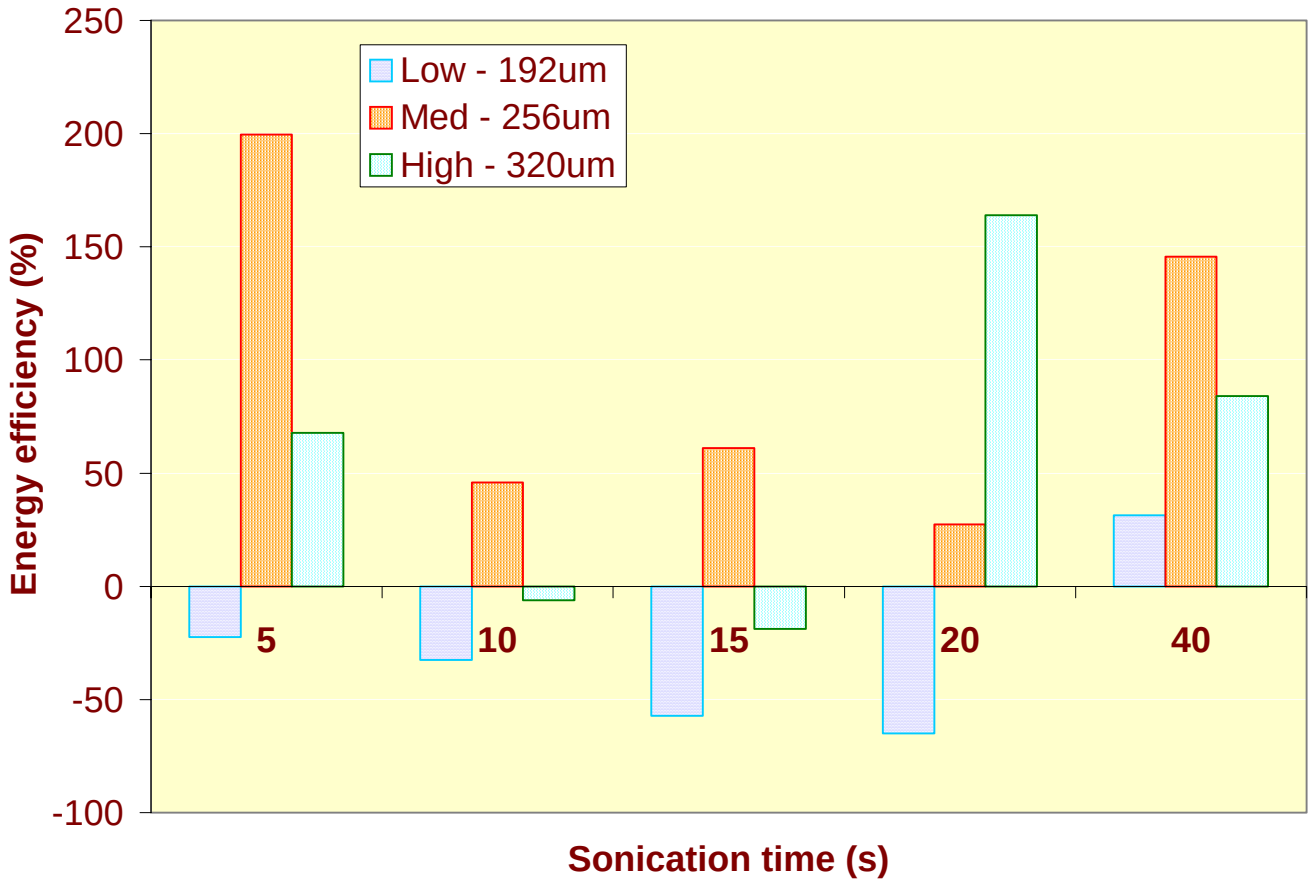
70-72°C
for 250s



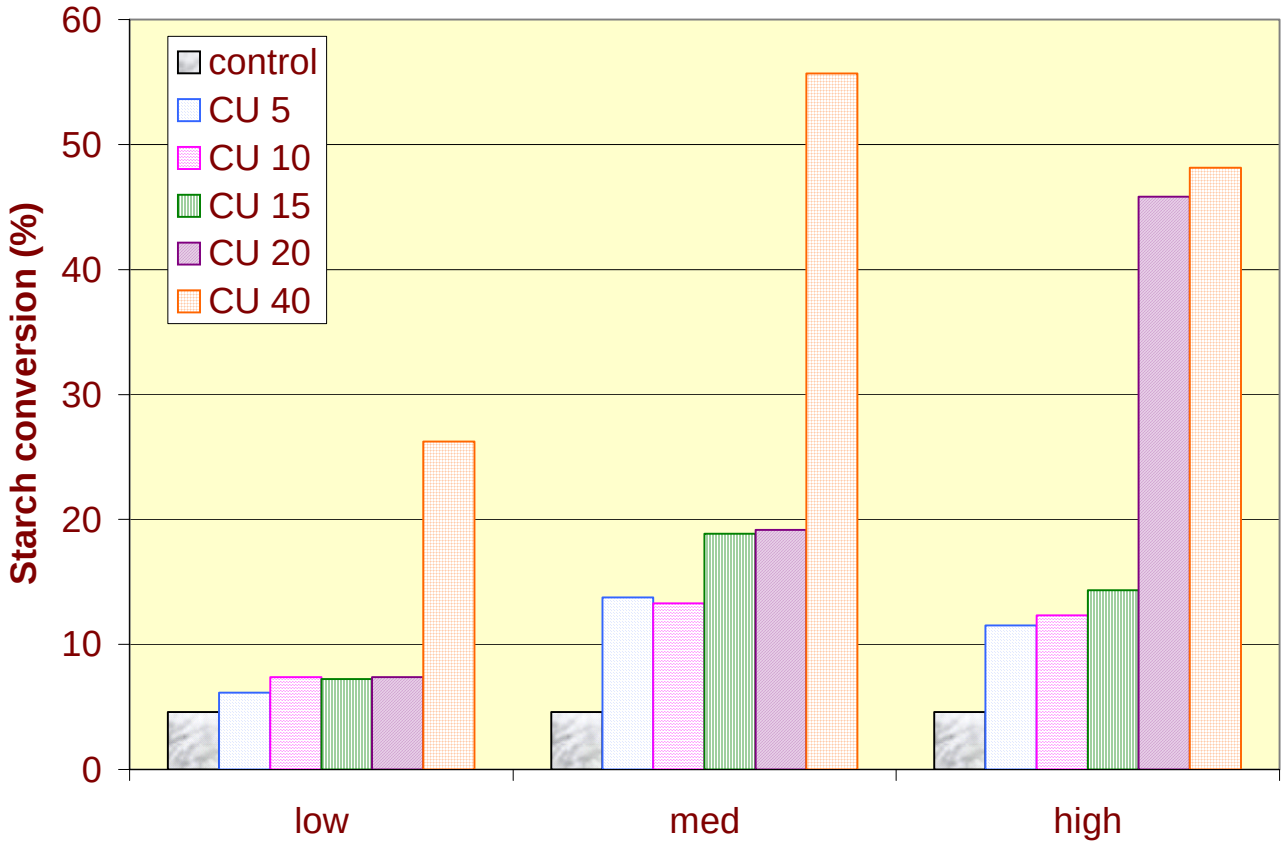


Sonicated
for 40s

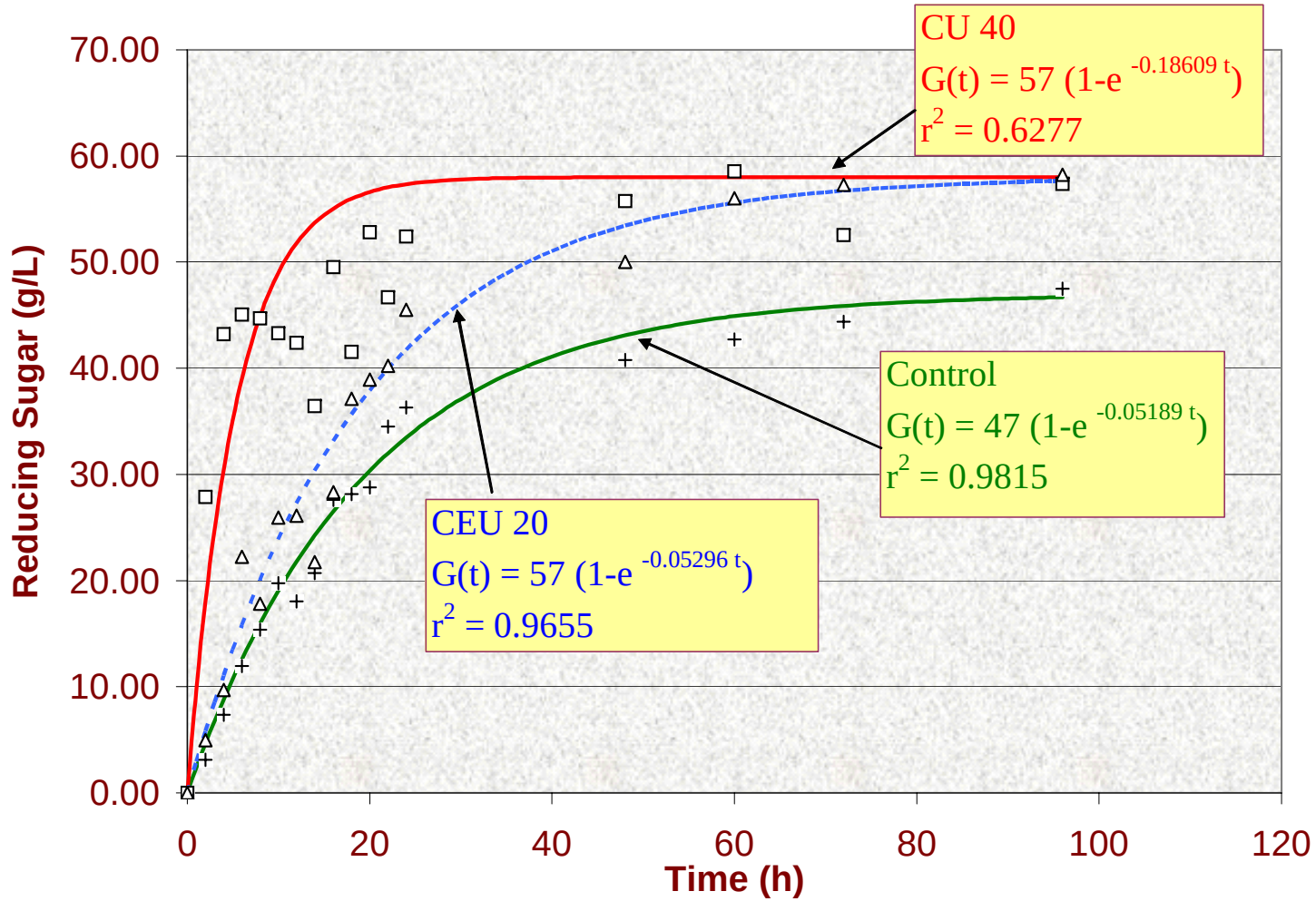
ENERGY BALANCE



STARCH CONVERSION

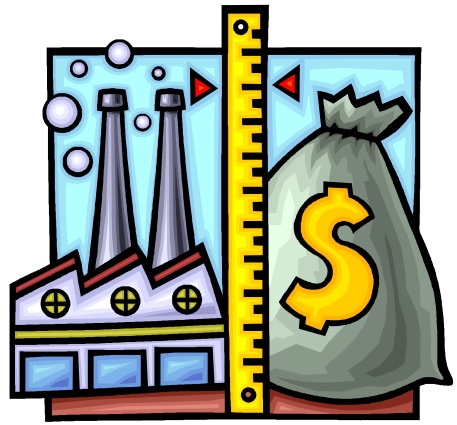


RESULTS (SACCHARIFICATION)



SUMMARY

This study investigates the potential of ultrasonics as a liquefaction pretreatment in corn ethanol plants



- reduced particle size of corn to 50-fold
- increased sugar yield by 30%
- sonicating corn slurry with enzymes has higher yield at low and medium amplitudes
- enzymes was denatured at high amplitudes
- enzymes was not denatured at temperature controlled experiments
- ultrasonics aids gelatinization

ACKNOWLEDGEMENT

Thanks to:

- **Grow Iowa Value Funds**
- **Branson Ultrasonics**
- **Lincolnway Energy Inc.**
- **Midwest Grain Processors**
- **Genencor International**

IOWA STATE UNIVERSITY