NC STATE UNIVERSITY

北京大学

Anaerobic Co-Digestion of Animal Manure and Agricultural Residues for Biogas Production

Jay J. Cheng (成 家 杨)

Peking University-Shenzhen Graduate School
North Carolina State University

@

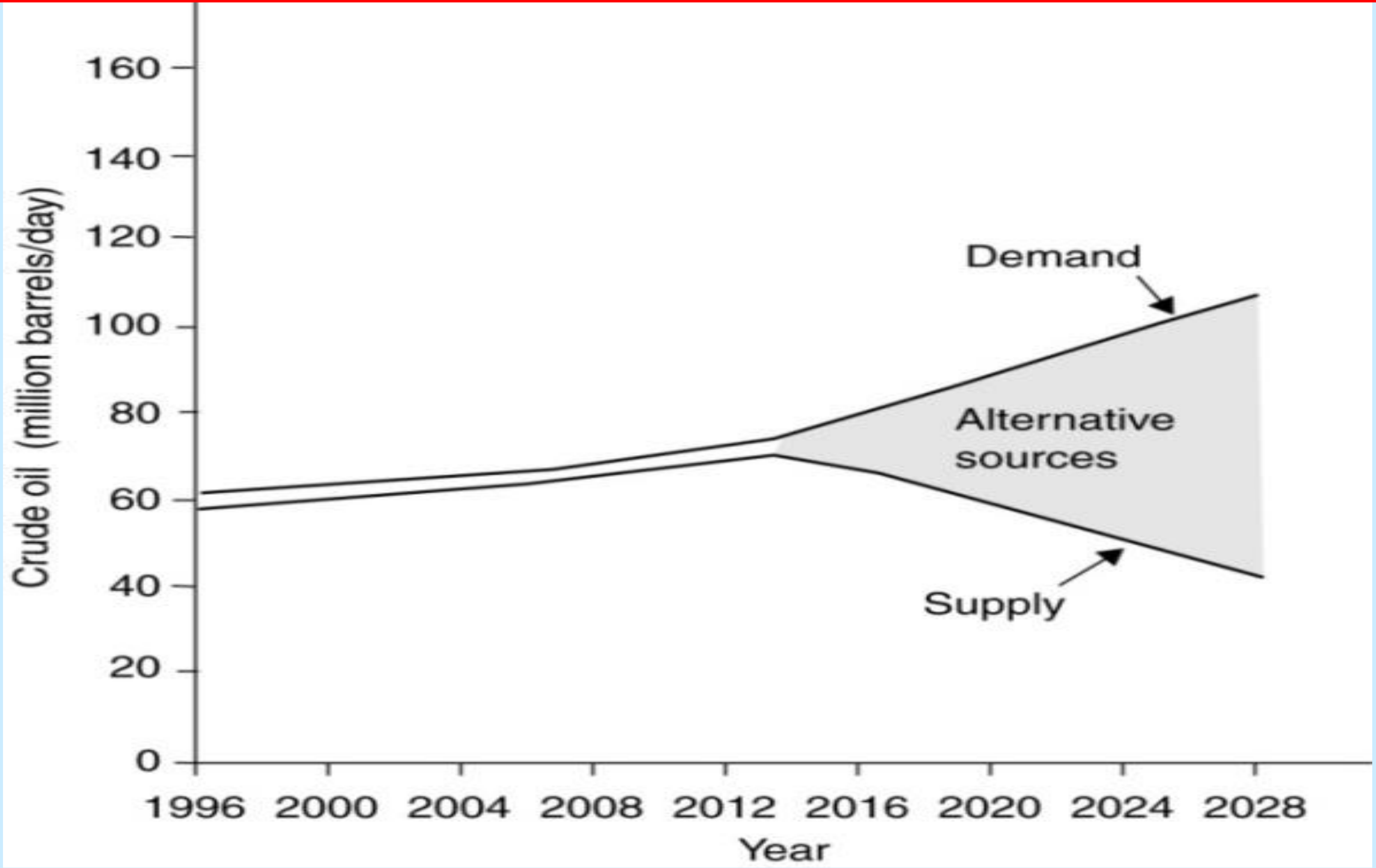
生質能源處理技術研討會・台北

2015 年 7 月 17 日

Background

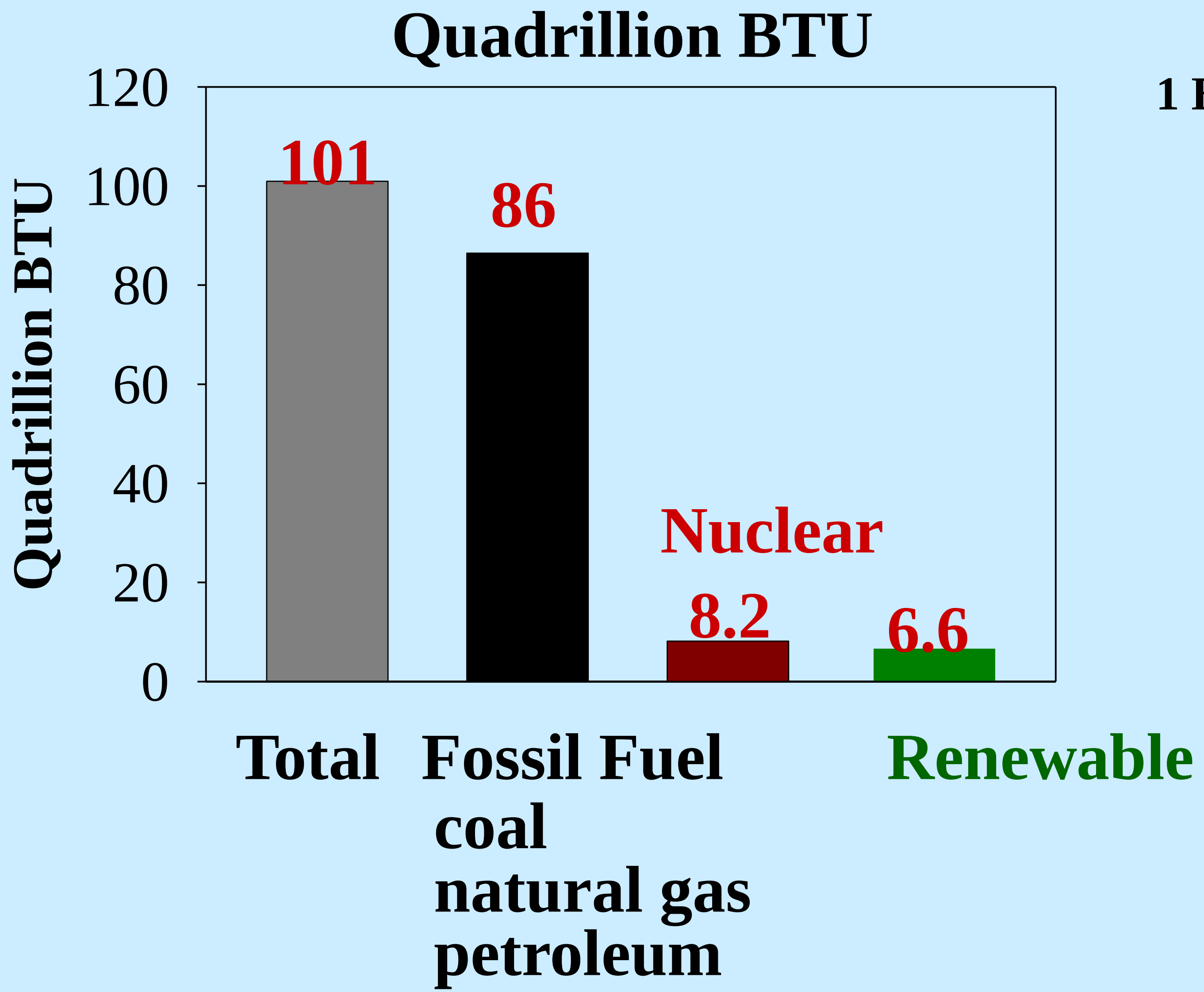
- Two big challenges:
  - **Energy demand**
  - **Global climate change**

Prediction of Energy Supply and Demand



Source: International Energy Agency

Energy Consumption in US (2008)



1 BTU =

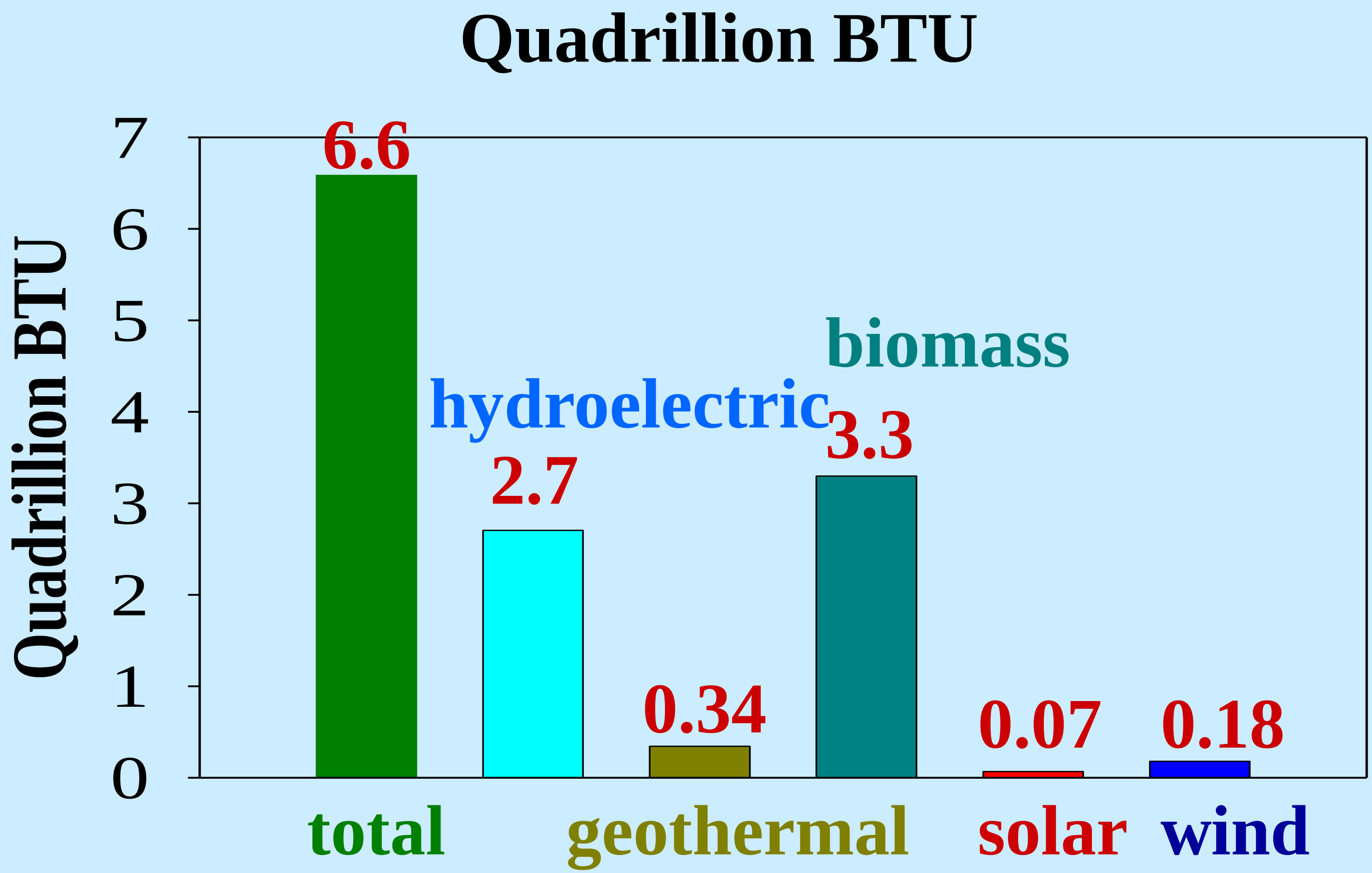
252 Cal.

1054 Joules

0.0003 kWh

Source: US DOE, 2009

Renewable Energy in US (2008)



Source: US DOE, 2009

Biogas: Energy Cinderella

Bio-ethanol

Bio-diesel

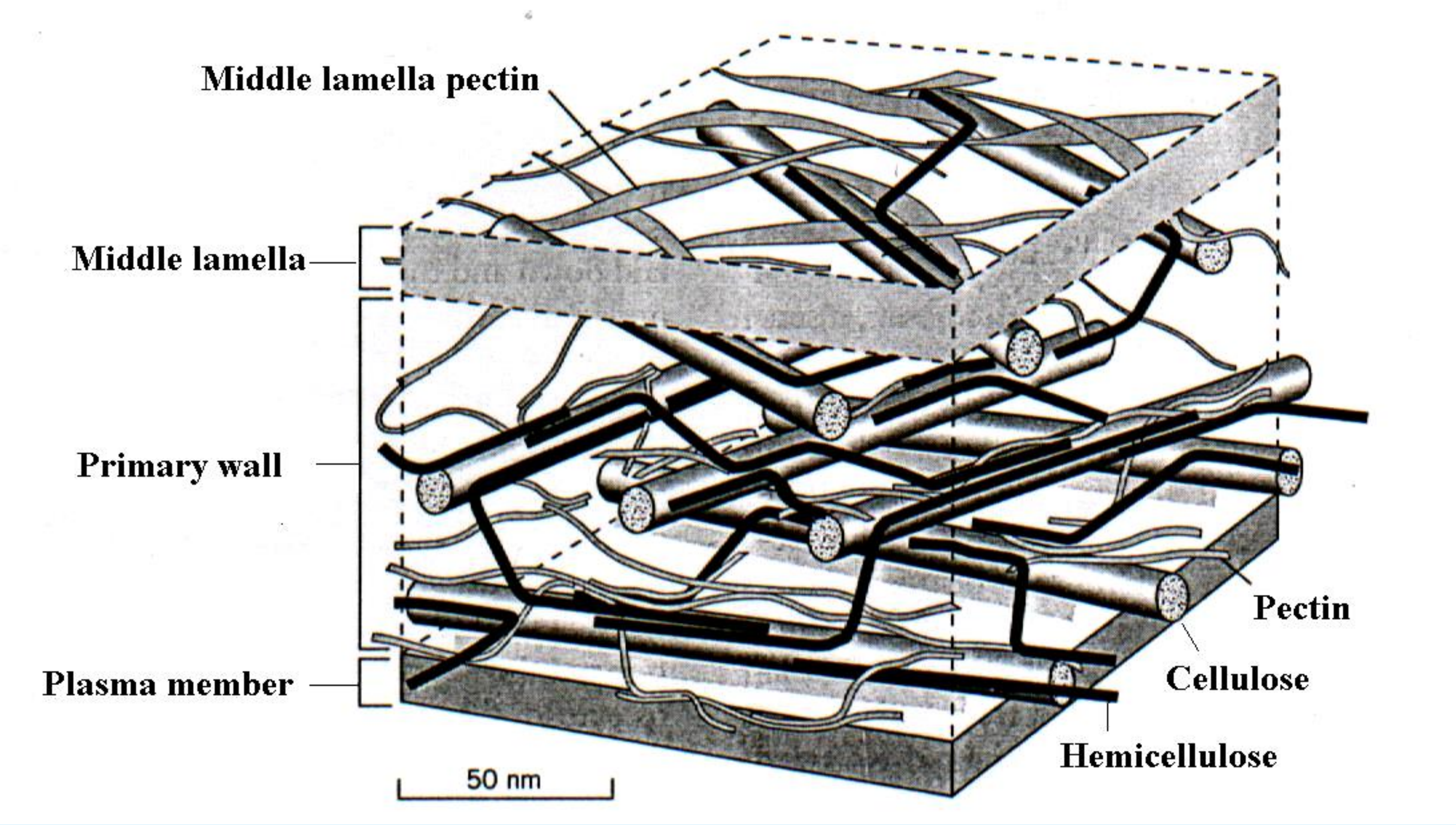
- Complex processes
- High cost
- Low net energy production
- Expensive to separate

Biogas:
Bio-methane

- Simple process
- Relatively low cost
- High net energy production
- Easy to separate

Lignocellulosic Materials

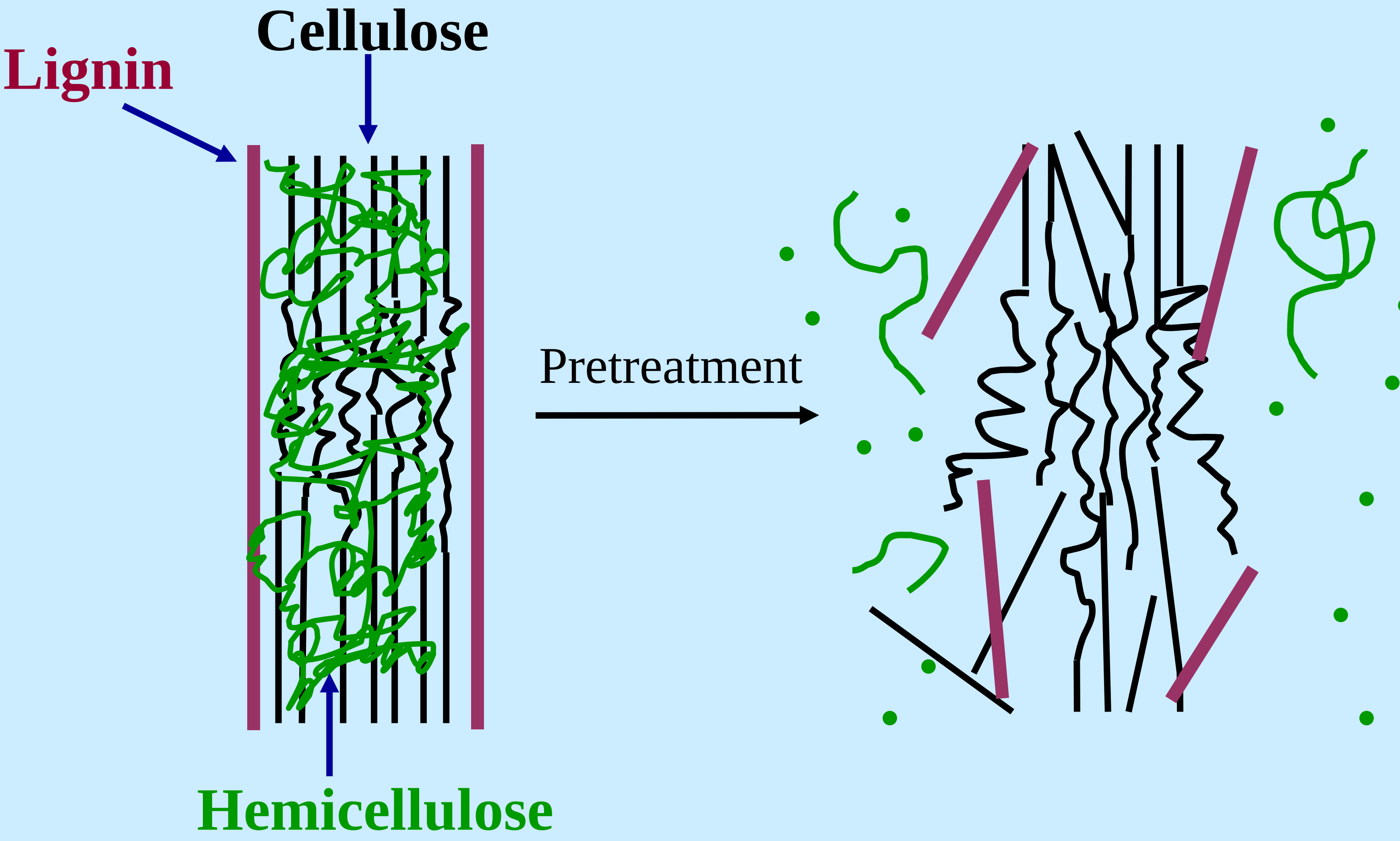
Structure of Lignocellulosic Biomass



Source: Hopkins, W.G., 1999. Introduction to Plant Physiology, second edition.

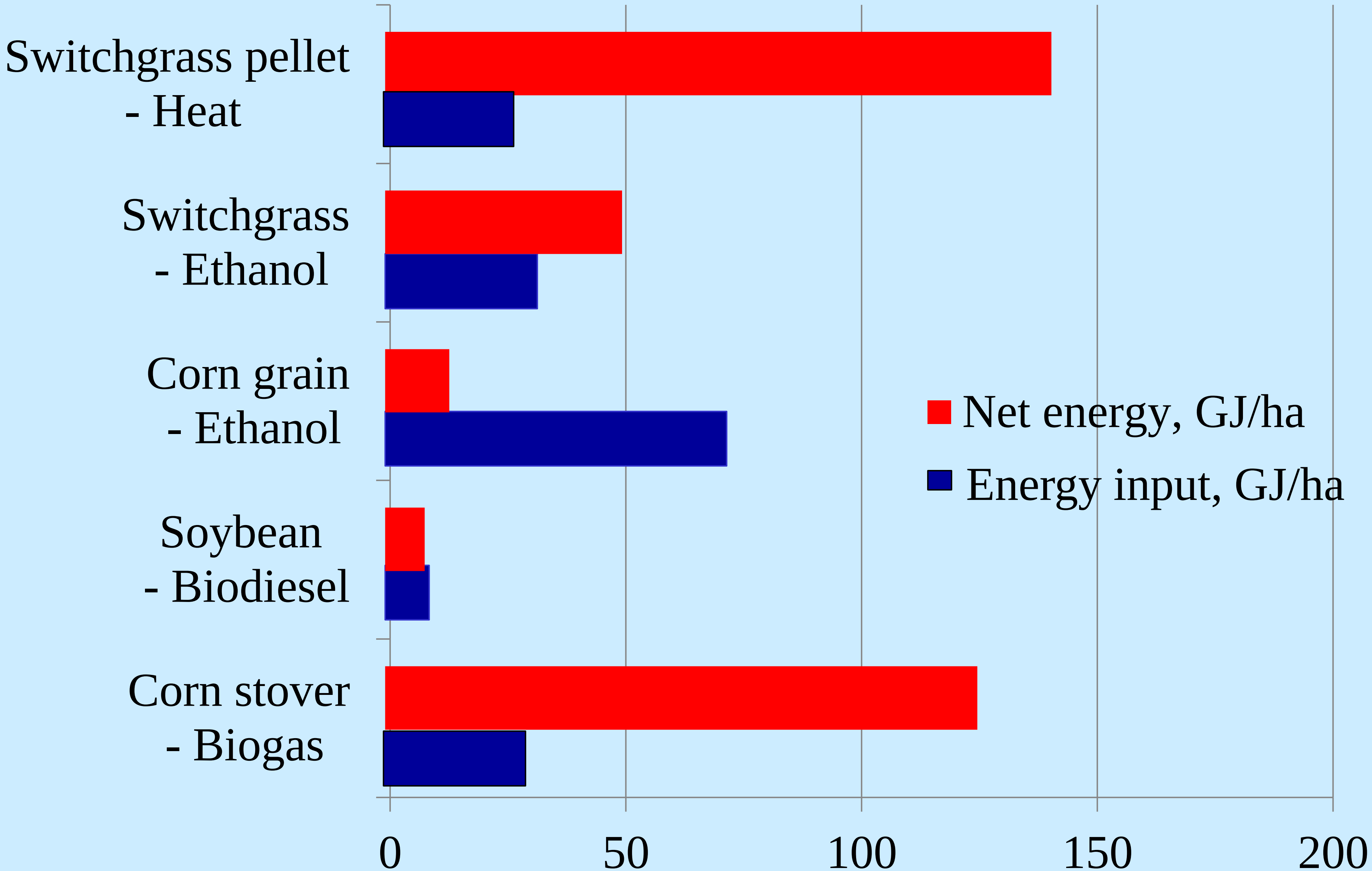
John Wiley & Sons, Inc., New York.

Pretreatment



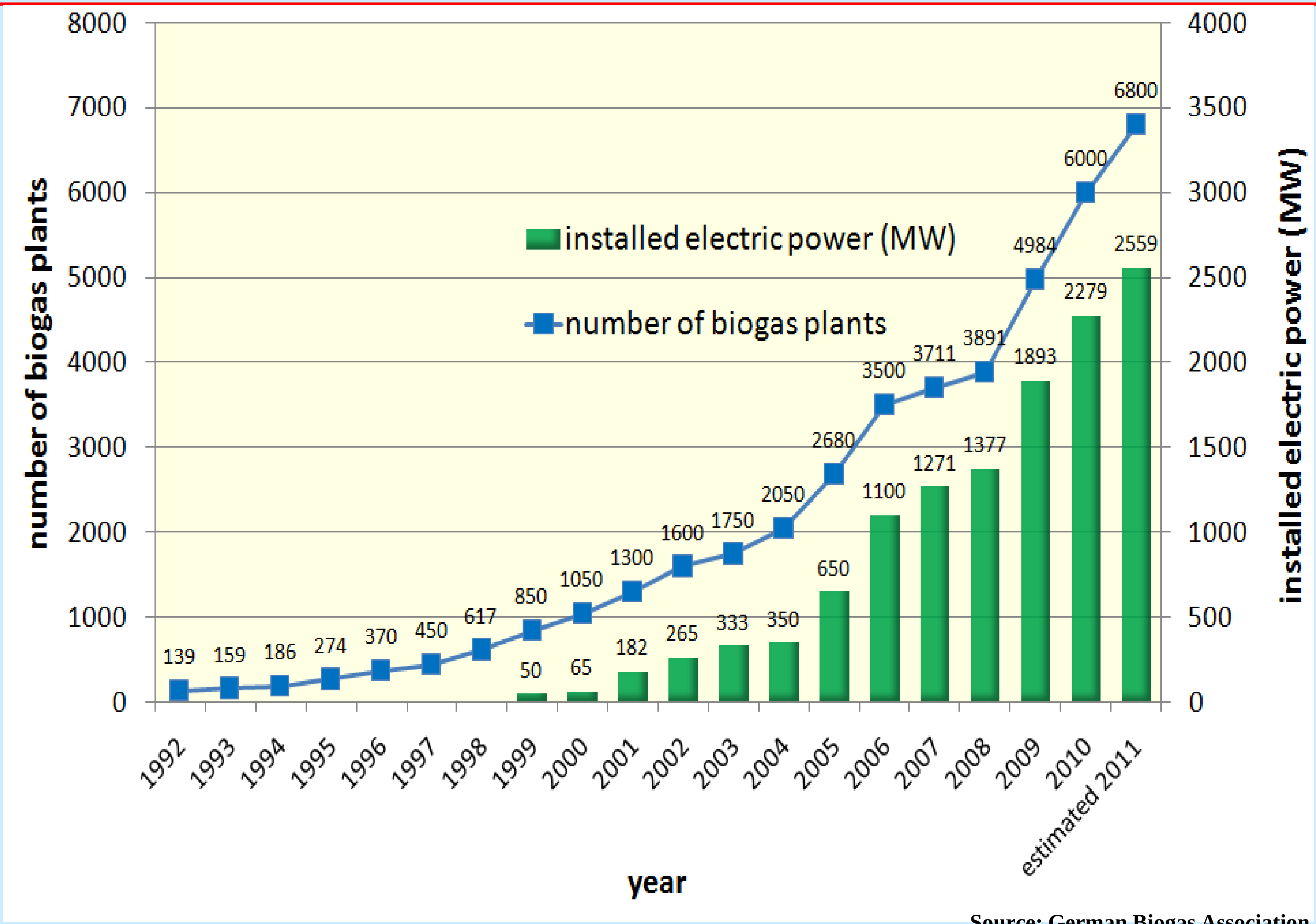
Ladisch, 2006

Biogas production vs. Other energy froms



Source: Samson et al. 2009

Biogas Production in Germany



Source: German Biogas Association, 2011

Anaerobic Co-digestion of Animal Manure and Agricultural Residues

Optimal C:N ratio for anaerobes: ~ 25 : 1

Typical C:N ratio for most agricultural residues: 60-80 : 1

Typical C:N ratio for animal manure: 5-10 : 1

Sources: Cheng & Liu, 2000; Demirbas, 2008; Hills and Roberts, 1981

Objectives

- **Investigate methane production from anaerobic co-digestion of swine manure and corn stover in a completely stirred tank reactor**
- **Study the effect of pretreatment on methane production from the anaerobic co-digestion**

Experimental Setup

Reactor 1 Reactor 2

- 2 CSTRs
- 14 L working volume
- Temperature: 35 C
- HRT: 25 days

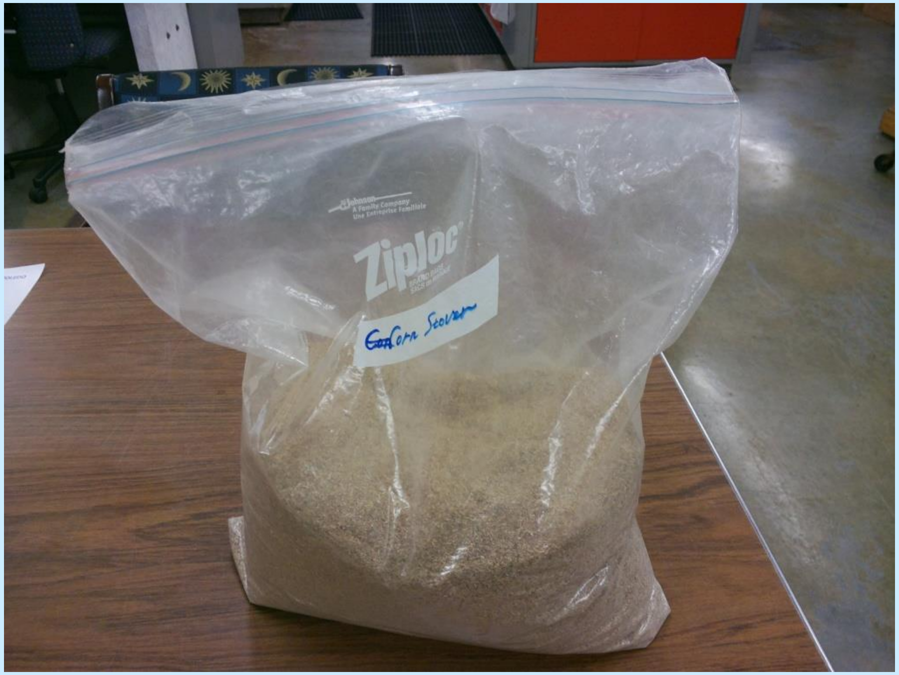
NC STATE UNIVERSITY

北京大学

Substrates

Swine Wastewater

Corn Stover



Reactor Operation

	Reactor 1 (control)	**Reactor 2**
Swine Wastewater	560 ml/d	560 ml/d
Corn Stover	No	14 g/d
C:N	2.3 : 1	10 : 1

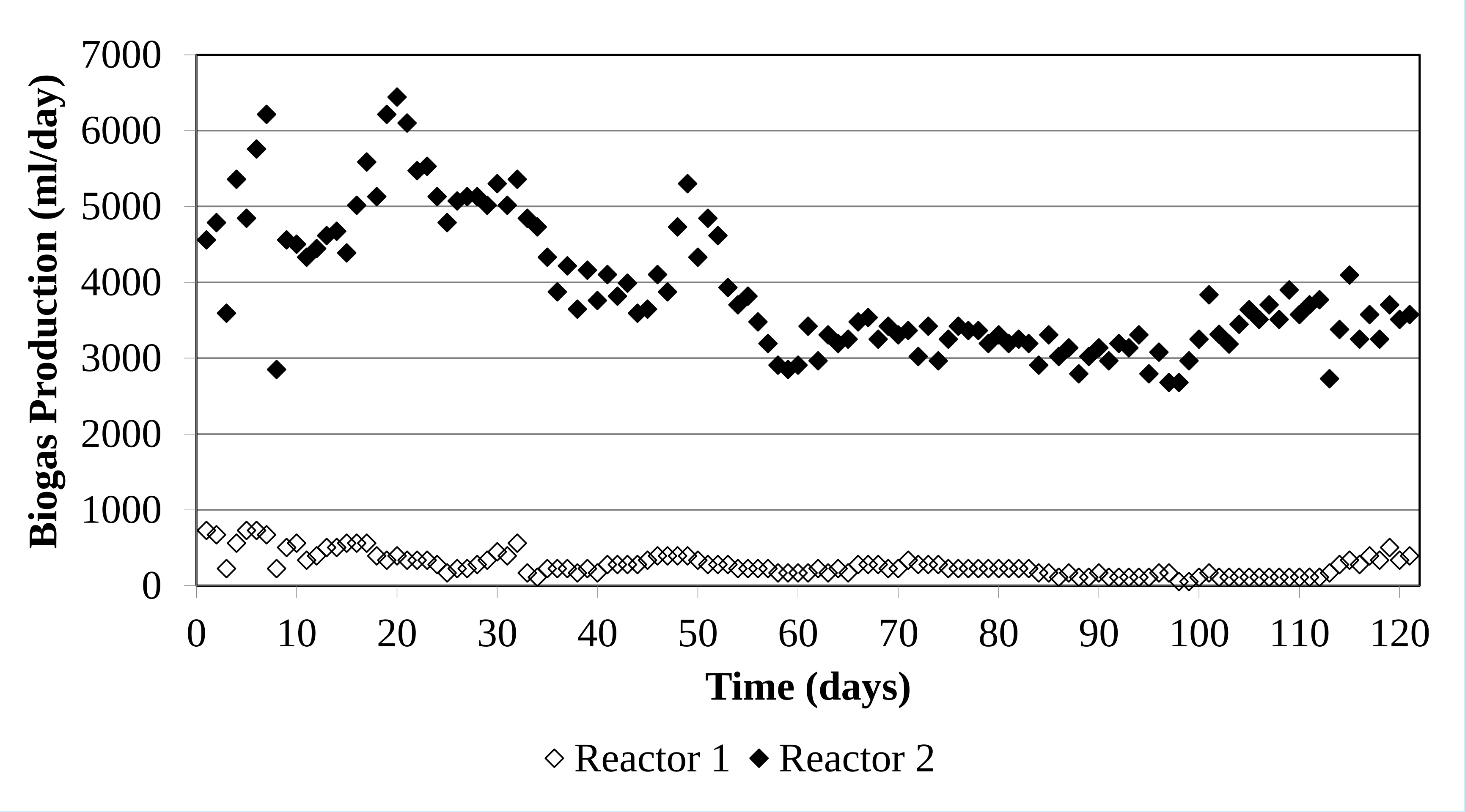
C:N (corn stover) = 52.6 : 1

Results and Discussion

Parameter	Removal efficiency (%)	
	Reactor 1	Reactor 2
COD	52	53
TKN	1	10
NH4-N	-51	15
Total P	14	14
TSS	54	58
VSS	51	58

Results and Discussion

Biogas Production



Results and Discussion

	Reactor 1 (control)	Reactor 2
Biogas Production (ml/day)	274	3910
Methane %	67.8	50.7
Methane production (ml/day)	186	1982

Results and Discussion

Methange Yield:

$$\text{Reactor 1} = 0.19 \; \frac{m^3 \text{ of } CH_4}{\text{kg of COD removed}}$$

$$\text{Reactor 2} = 0.18 \; \frac{m^3 \text{ of } CH_4}{\text{kg of COD removed}}$$

Effect of Pretreatment

Pretreatment method:

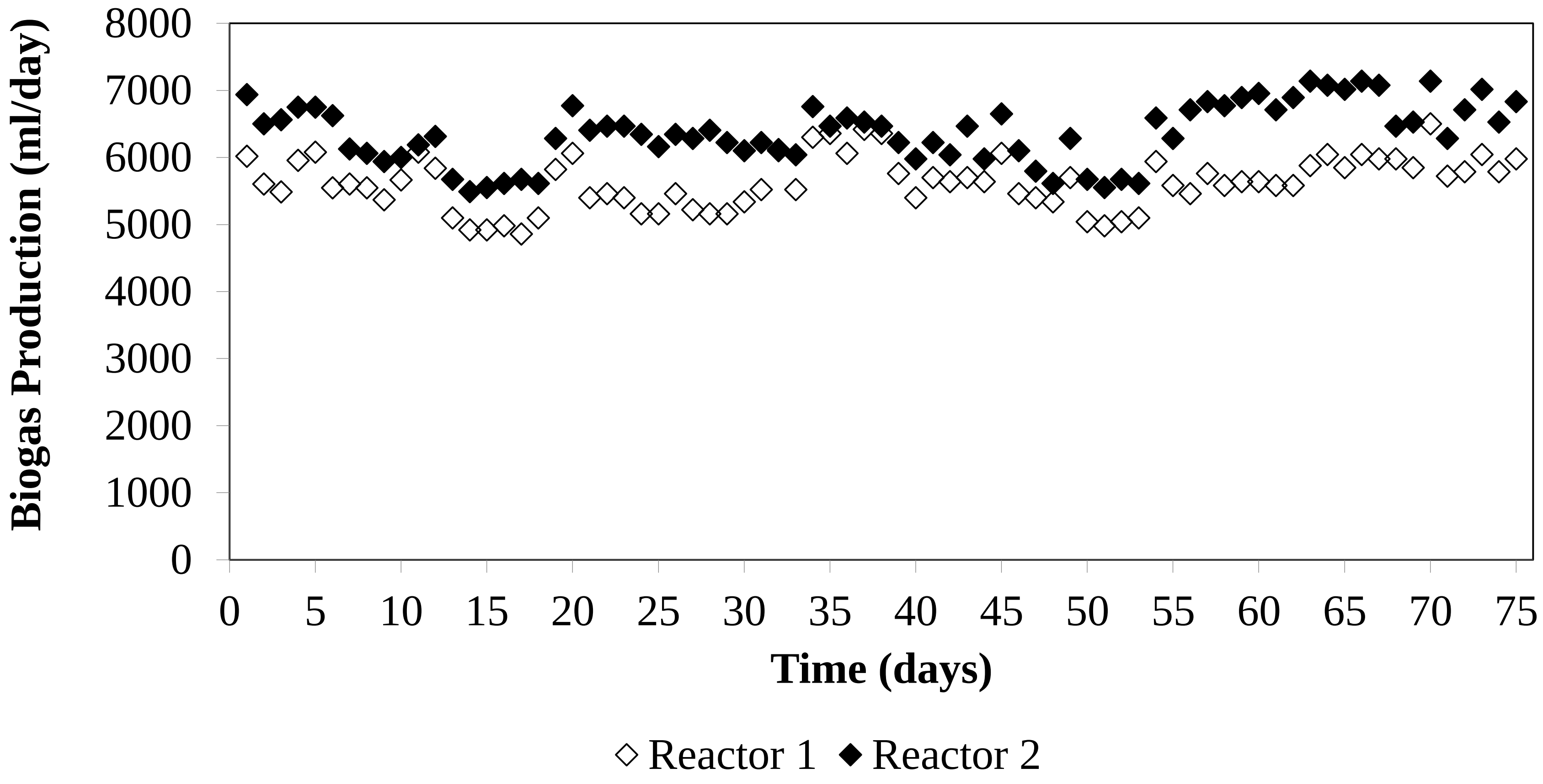
Cellulase pretreatment: pH 4.5-7.5; T 35-65° C

Protease pretreatment: pH 7.0-10.0; T 40-80° C

Alkaline pretreatment: 5% of NaOH and 5% of CaO; 6 hours; 21° C

Effect of Pretreatment

Biogas Production: Cellulase Pretreatment

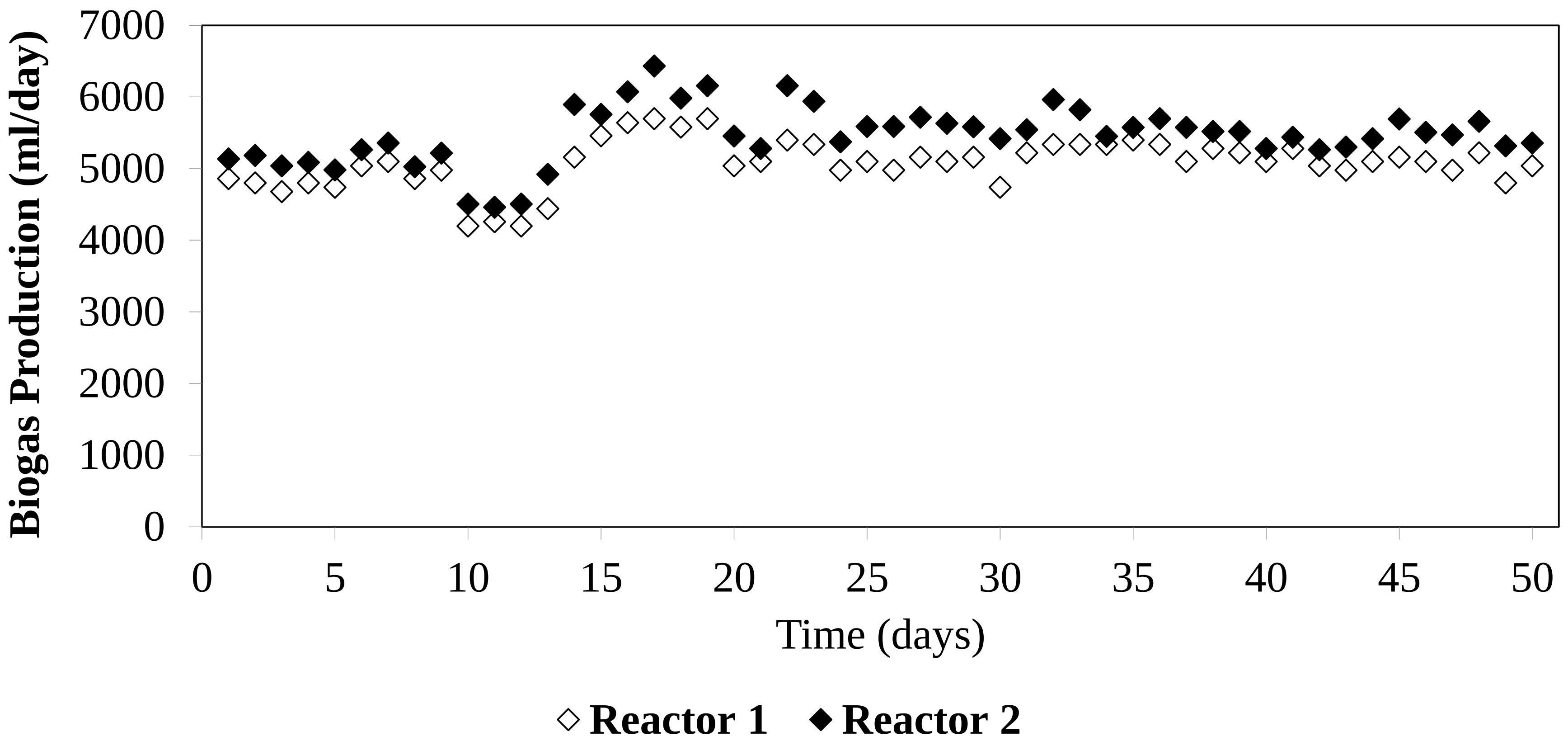


NC STATE UNIVERSITY

北京大学

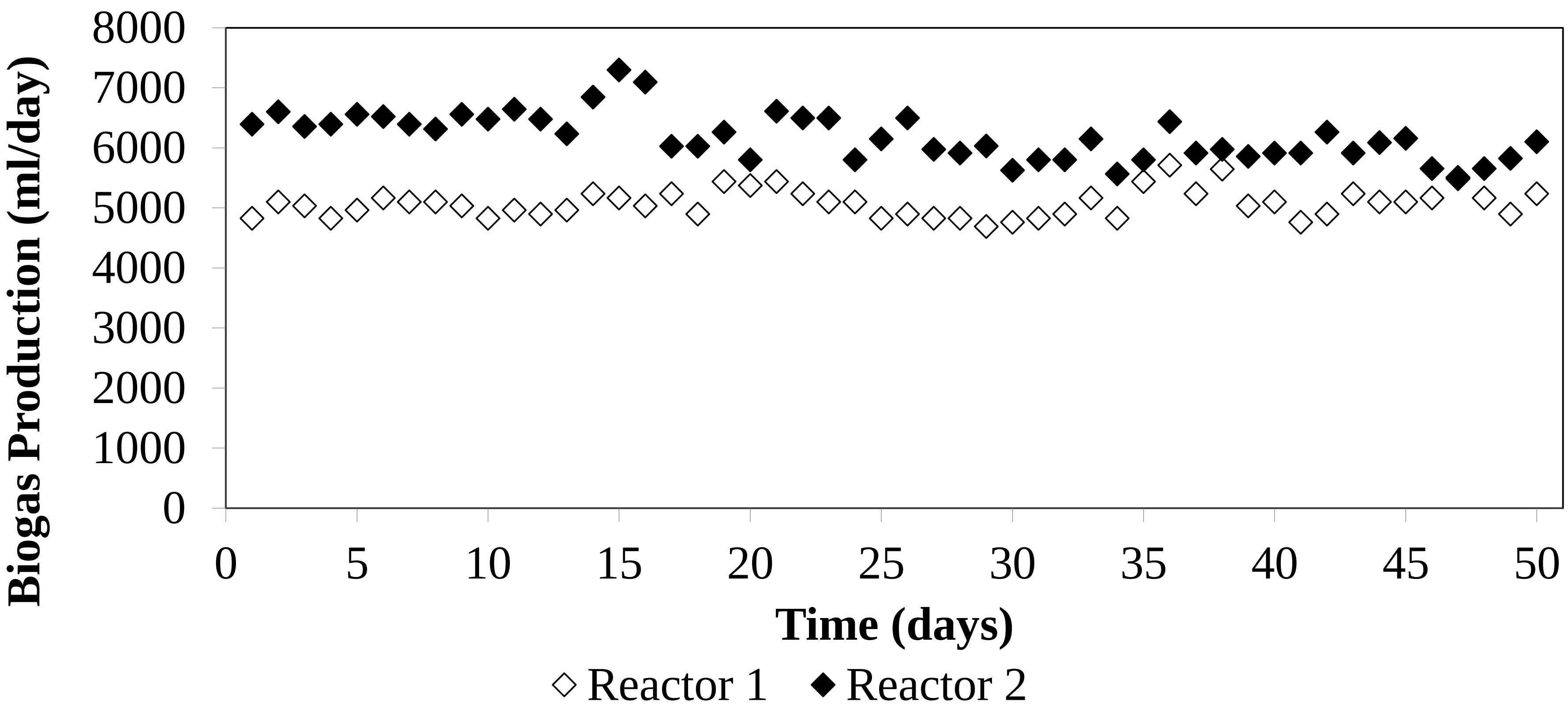
Effect of Pretreatment

Biogas Production: Protease Pretreatment



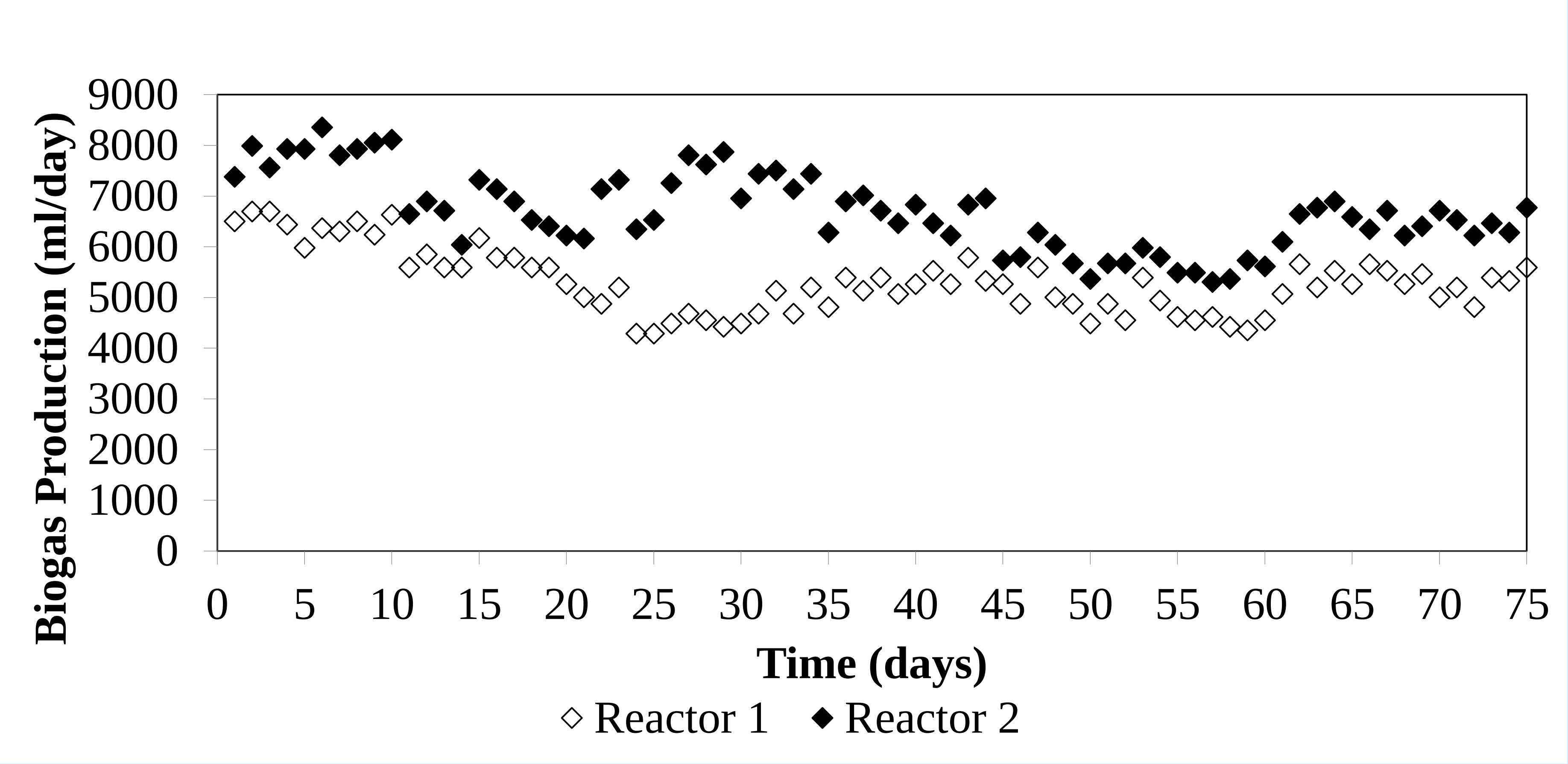
Effect of Pretreatment

Biogas Production: Alkaline Pretreatment



Effect of Pretreatment

Biogas Production: Alkaline + Cellulase Pretreatment



Effect of Pretreatment

Pretreatment	Methane yield increase (%)
Cellulase	10.40
Protease	5.50
Alkaline	21.80
Alkaline+Cellulase	31.90

Conclusions

- Corn stover could be substantially degraded to methane in an anaerobic co-digestion with swine manure.
- Addition of corn stover could balance the nutrients and significantly increase methane production.
- Alkaline pretreatment of corn stover could substantially improve methane production of the co-digestion.

Perspective of biogas production

Substrates:

- ✓ Organic wastes from households
- ✓ Sludge from municipal wastewater treatment plants
- ✓ Waste food from restaurants, grocery stores, and food manufacturers
- ✓ Animal manure and processing wastes
- ✓ Agricultural residues
- ✓ Wastewaters from alcohol and non-alcohol beverage plants

Agricultural Biogas Potential in US

- **Agricultural Residues**
  - **Corn stover:**
    460 Million tons (dry)
  - **Wheat straw:**
    170 Million tons (dry)
  - **Cotton stalk:**
    27 Million tons (dry)
  - **Other straws: 89 Million tons (dry)**

- **Total Ag. Residues: 746 Million tons (dry)**

Agricultural Biogas Potential in US

- **Annual Animal Manure Production (million dry tons)**

Cattle and Calves	177.5
Hogs and Pigs	23.7
Chicken	131.7

Total animal manure production: 332.9

Biogas Potential in Mainland China

Organic Waste	Annual Production, ton (dry)/year	CH_4 potential, m^3/year
Municipal organic wastes	29.5×10^6	7.08×10^9
Septic feces	0.6×10^6	0.18×10^9
Sewage sludge	2.3×10^6	0.29×10^9
Agricultural residues	600×10^6	142×10^9
Animal manure	710×10^6	208×10^9
Total		**357×10^9**

Thank you!

? / !