南京工业大学
NANJING TECH UNIVERSITY

Biogas Production from Agro-waste in Nanjing Tech University: Research and Practice

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Beijing 10/23/2018

Outline

- **Background**
- **Research progress in Nanjing Tech University**
- **Commercial projects**
- **Acknowledgements**

Background

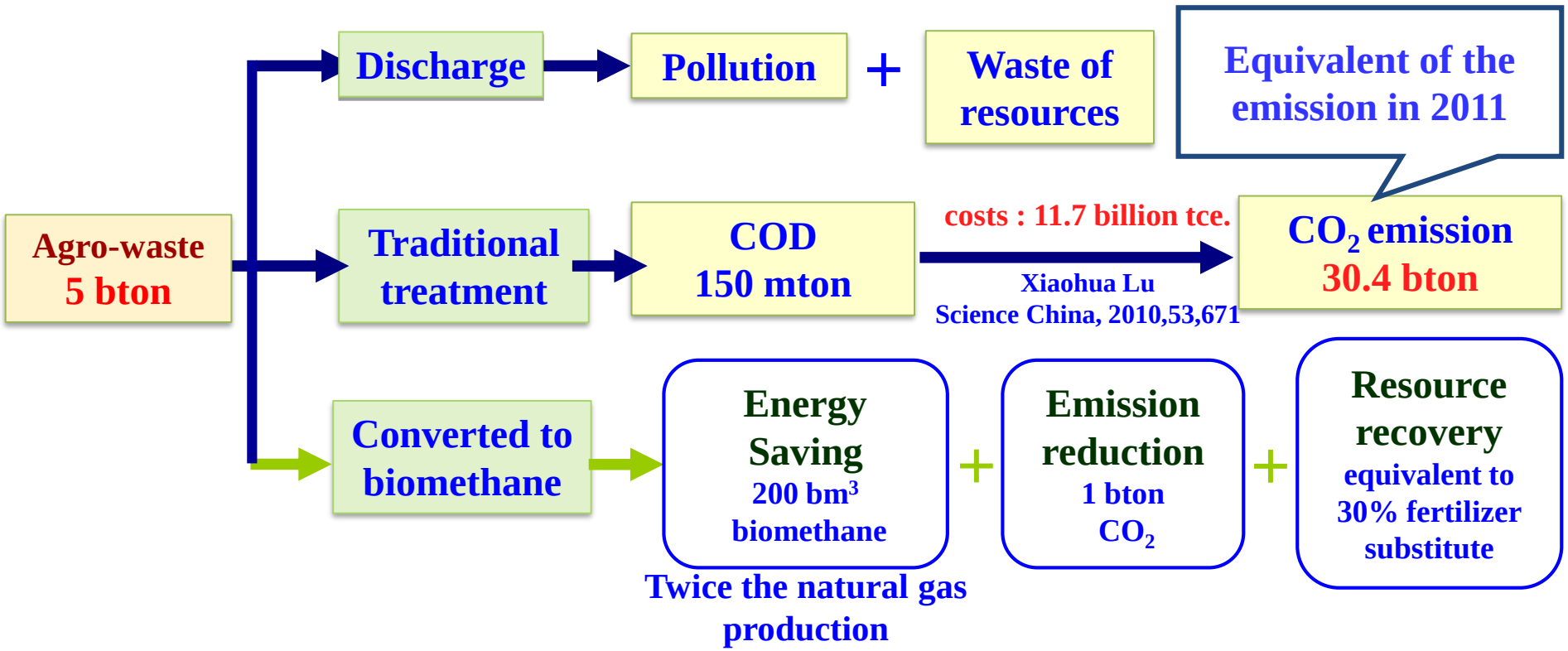
Agro-waste: important source of pollution in China

- **In China, around 5 billion tons of agro-waste was produced and discharged, and more than 40% of them were not disposed effectively.**

Agro-waste	Output（Mt/a）
Straw	700
Manure	3800
Kitchen waste	100
Municipal sludge	50
Fruit and vegetable waste	100

How to deal with agro-waste efficiently?

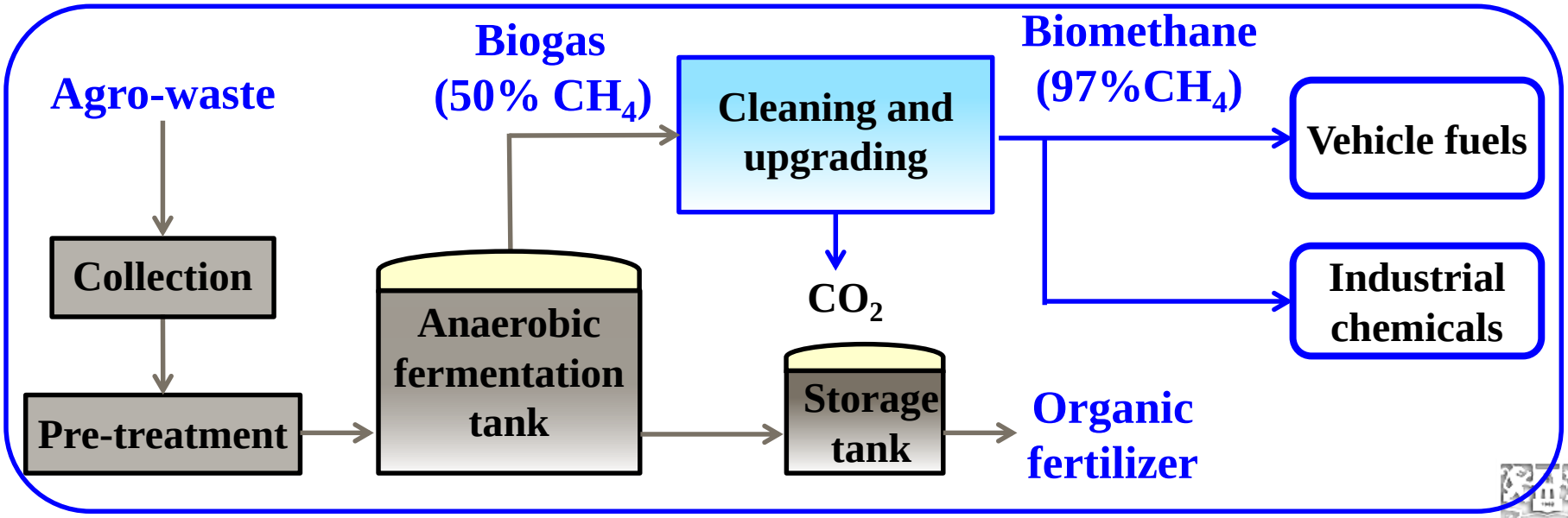
A sustainable way: Converting agro-waste to bioengergy



Strategic significance of high-efficient conversion of bioenergy: energy-saving, emission mitigation, and resource recovery

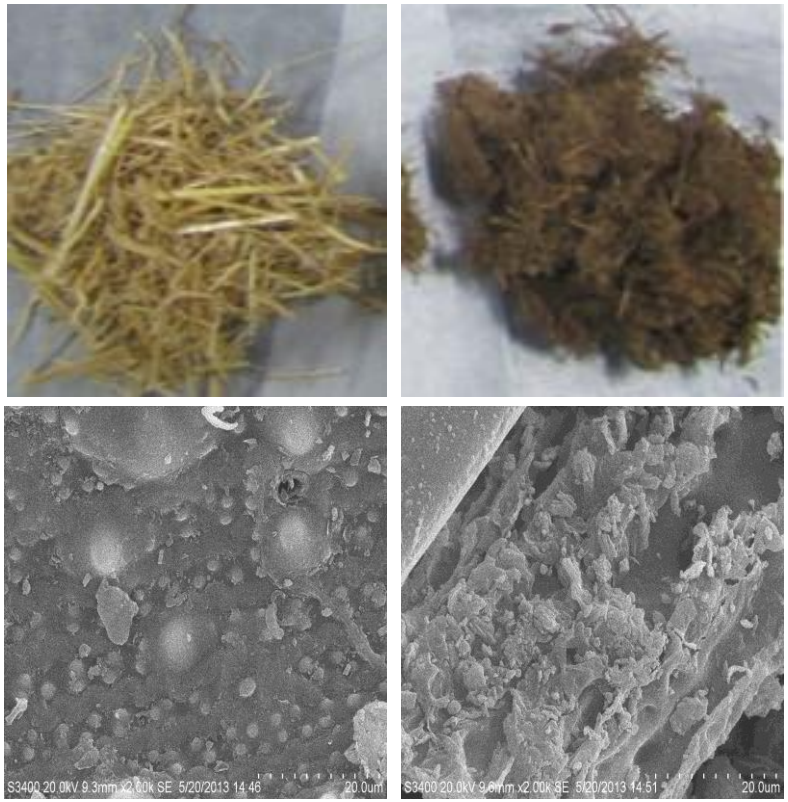
Agro-waste to biomethane

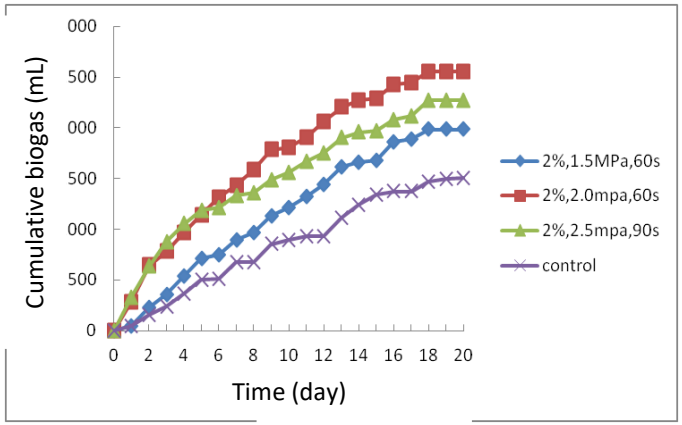
- **It is well-known to all, agro-waste can be converted to biogas via anaerobic digestion.**
- **Biogas was readily upgraded to biomethane and digestate was used in organic fertilizer via composting.**

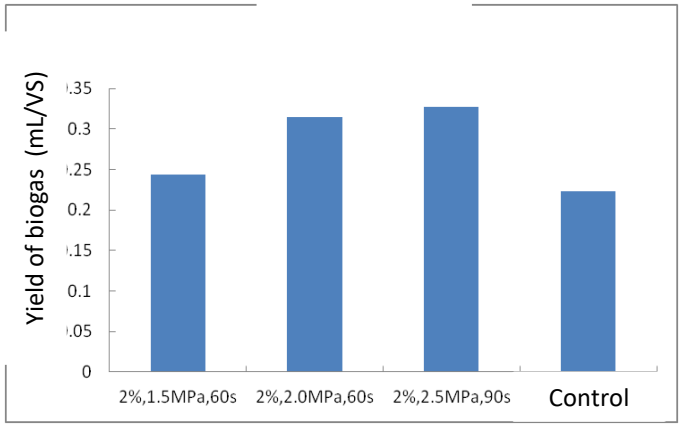


Research progress in Nanjing Tech University

Straw pretreated by steam explosion





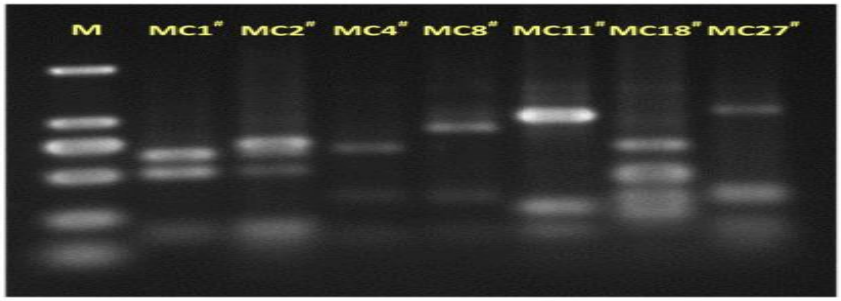


- **After steam explosion, the biogas production from straw increased by 70%, biogas production rate increased by 40% in the condition of 2.0 MPa, 60 s.**

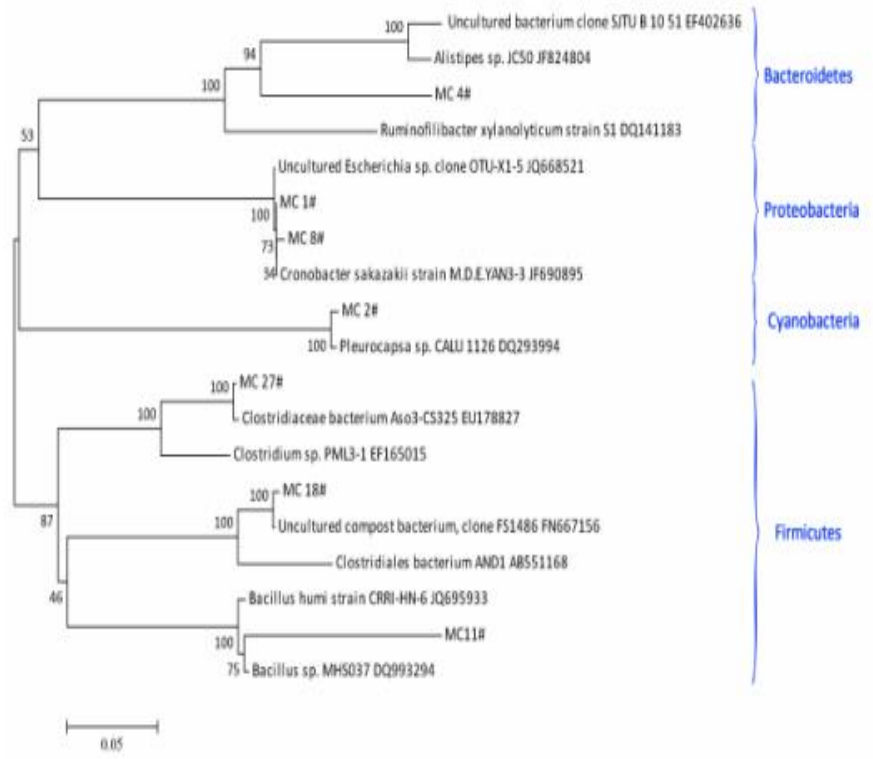
Identification and artificial construction of straw degrading microbial consortium

1st Day

14th Day

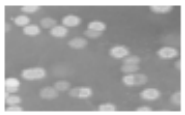
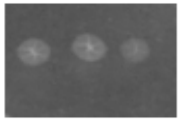
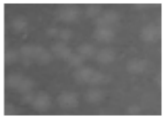
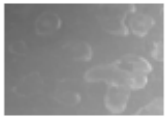
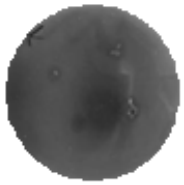
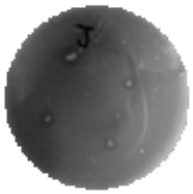
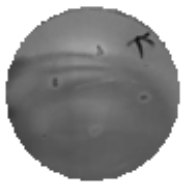


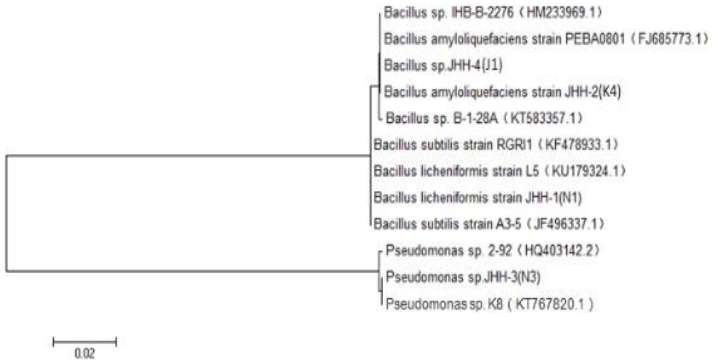
M stand for Marker (DL2000); MC stand for microbial consortium



- **A straw degrading microbial consortium was screened and some lignocellulosic degrading strains were identified.**

Identification and artificial construction of straw degrading microbial consortium

	N1	N3	K4	J1
Colony				
Size	1-3 mm	3-5 mm	1-3 mm	2-5 mm
Shape	Round	Round	Round	Round
Color	White	White	White	White
Transparency	Translucent	Translucent	Translucent	Transparent
Viscosity	Non-viscous	Viscous	Non-viscous	Viscous
Cellulose decomposing test				
Hemicellulose decomposing test		/		



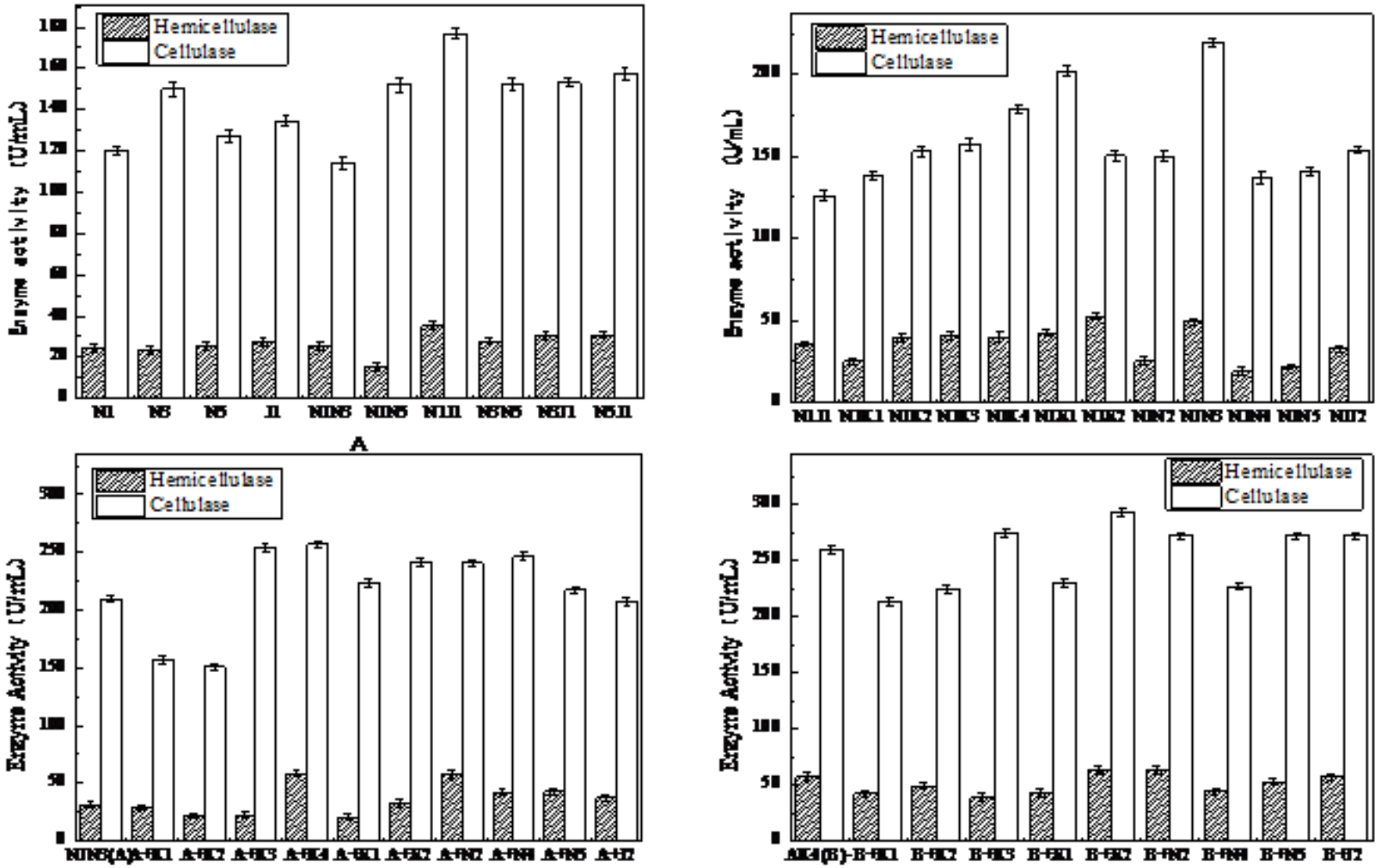
N1： ***Bacillus licheniformis***

N3： ***Alcaligenes faecalis***

K4： ***Bacillus amyloliquefaciens***

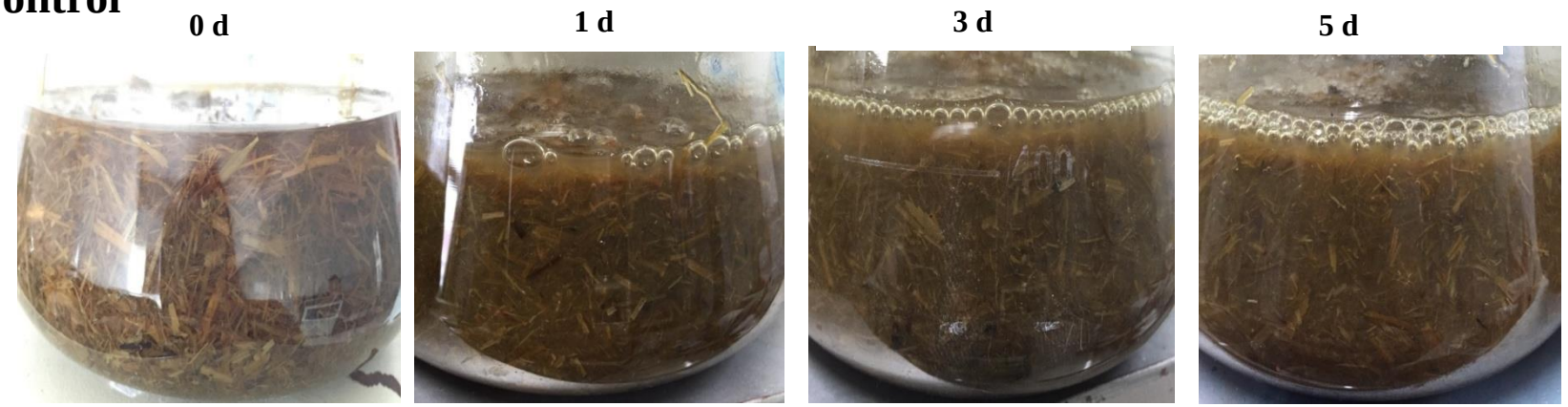
J1： ***Bacillus subtilis***

Identification and artificial construction of straw degrading microbial consortium

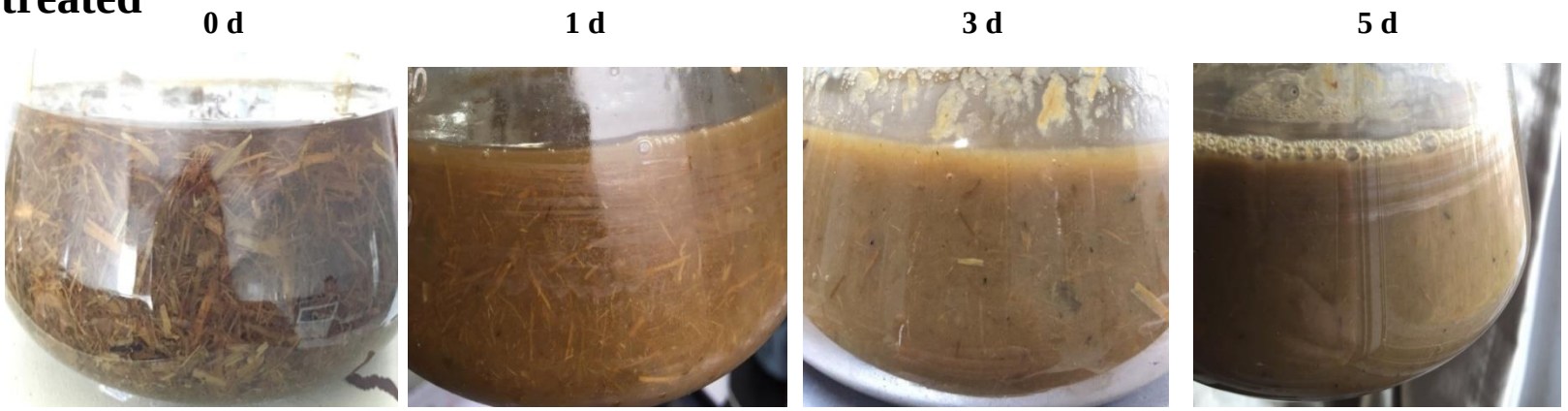


Identification and artificial construction of straw degrading microbial consortium

Control

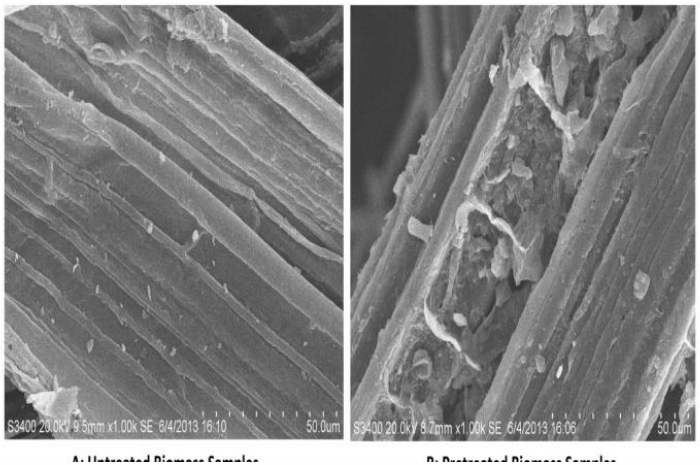


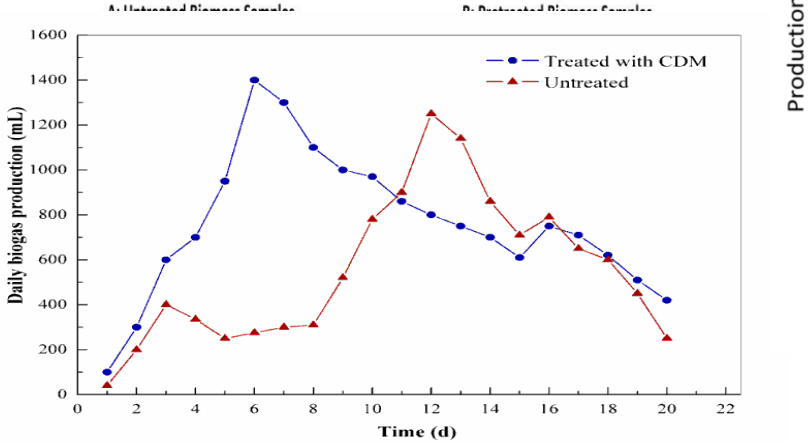
Pretreated

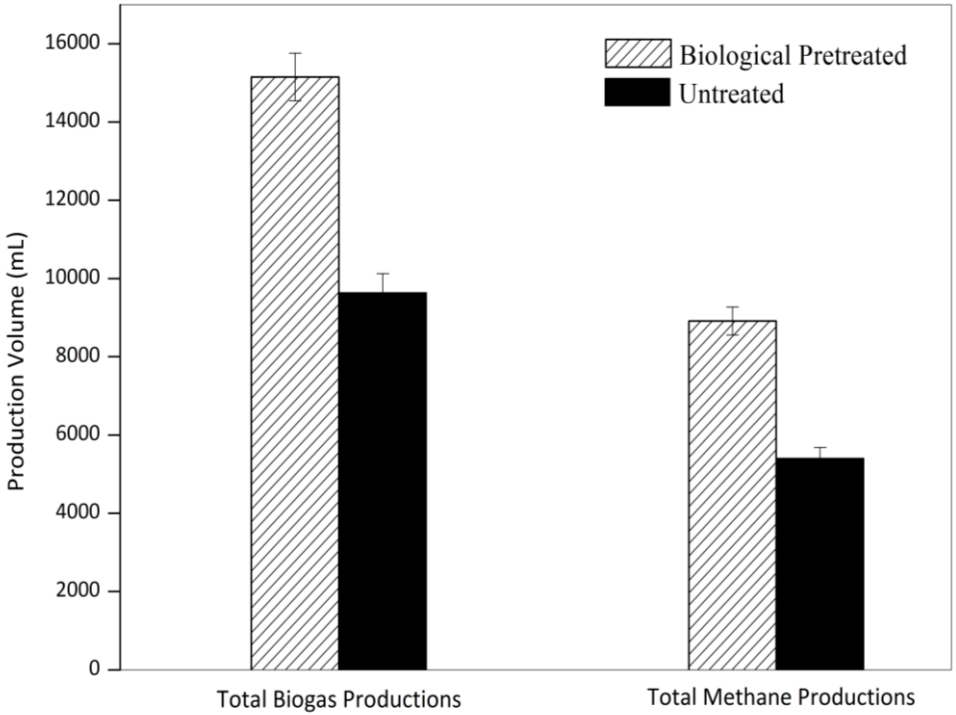


- **Artificial microbial consortium decomposed straw into fragments efficiently.**

Biogas production from straw pretreated by microbial consortium

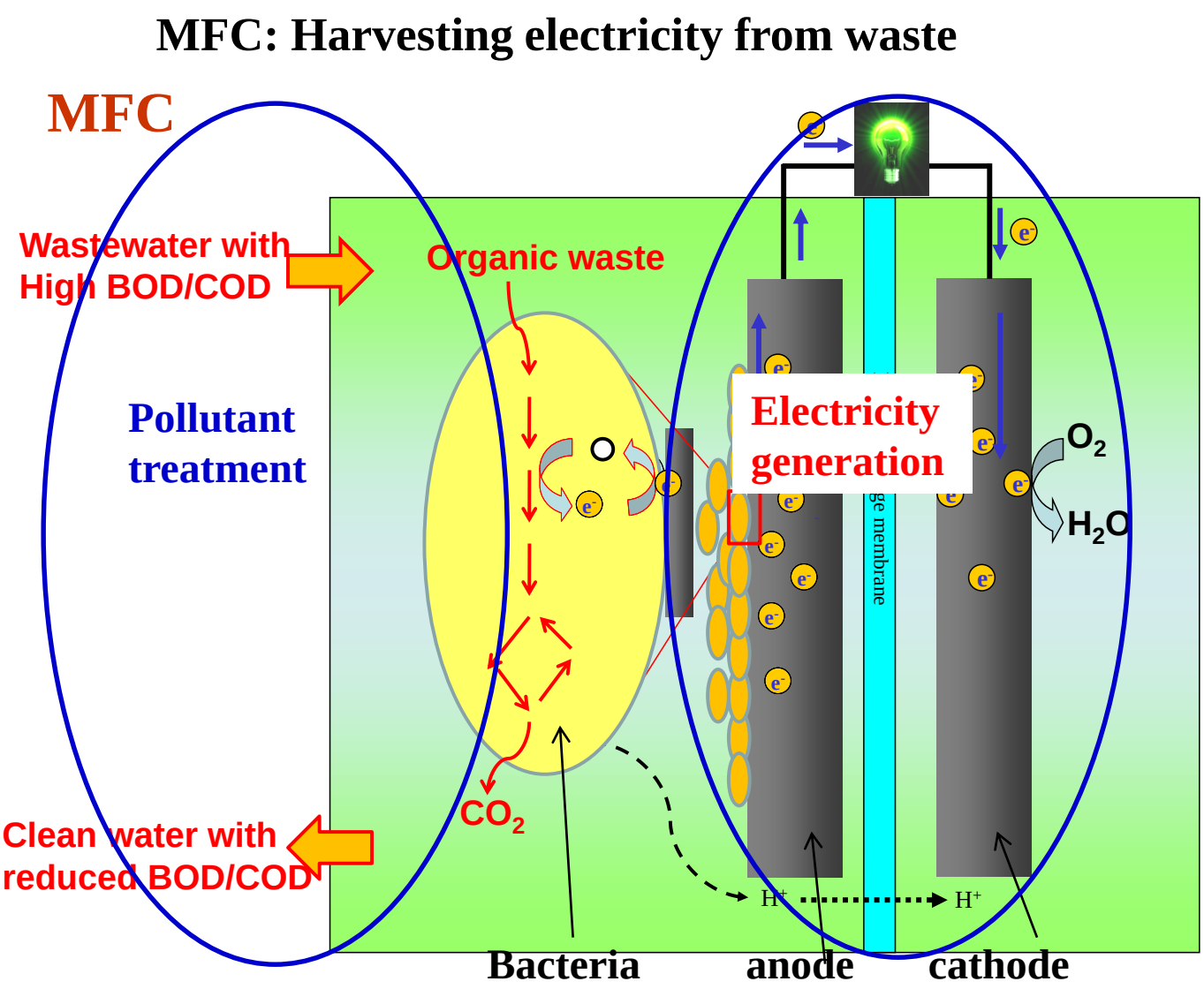


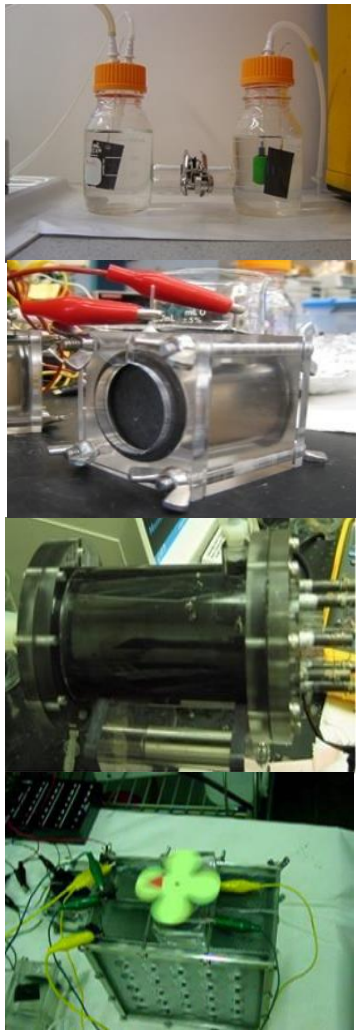




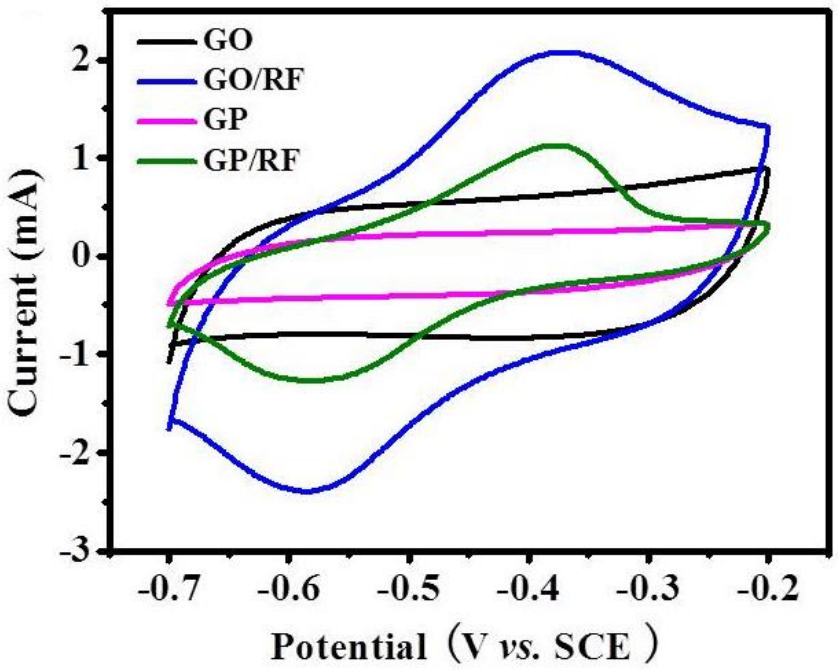
- **Compared to untreated straw, the biogas production from straw pretreated by microbial consortium increased by 40% after 40 days of anaerobic digestion.**

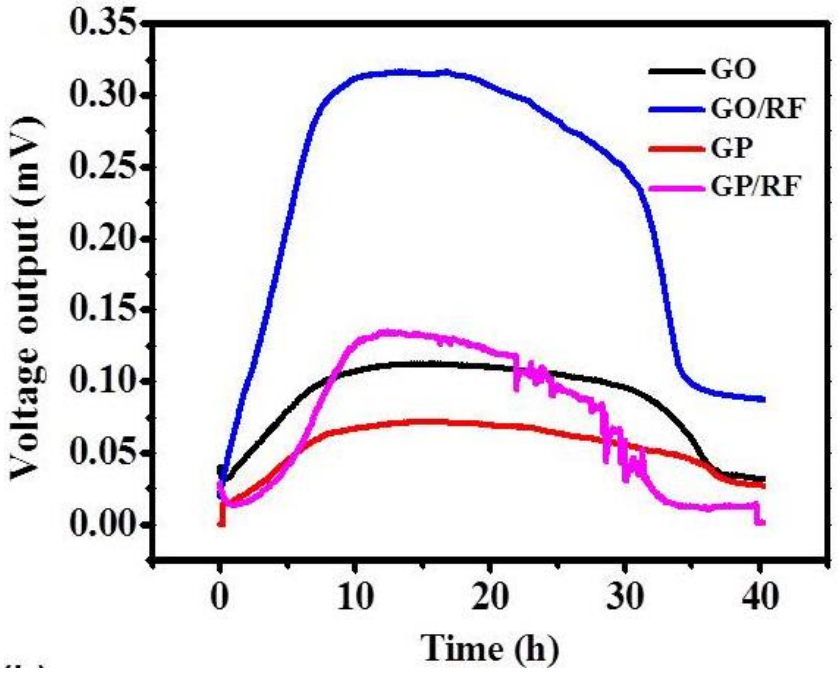
Integration of biogas production with microbial fuel cell (MFC)





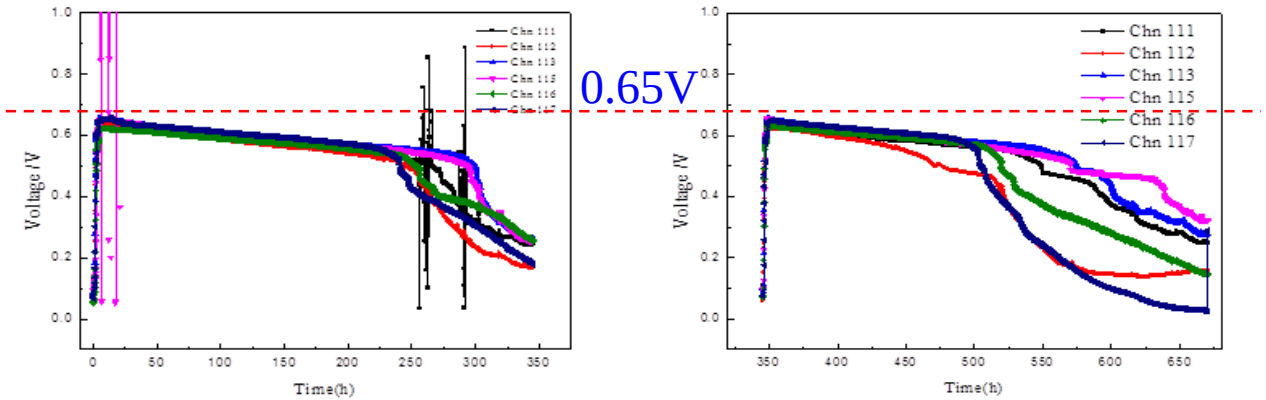
Graphene modified electrode in MFC



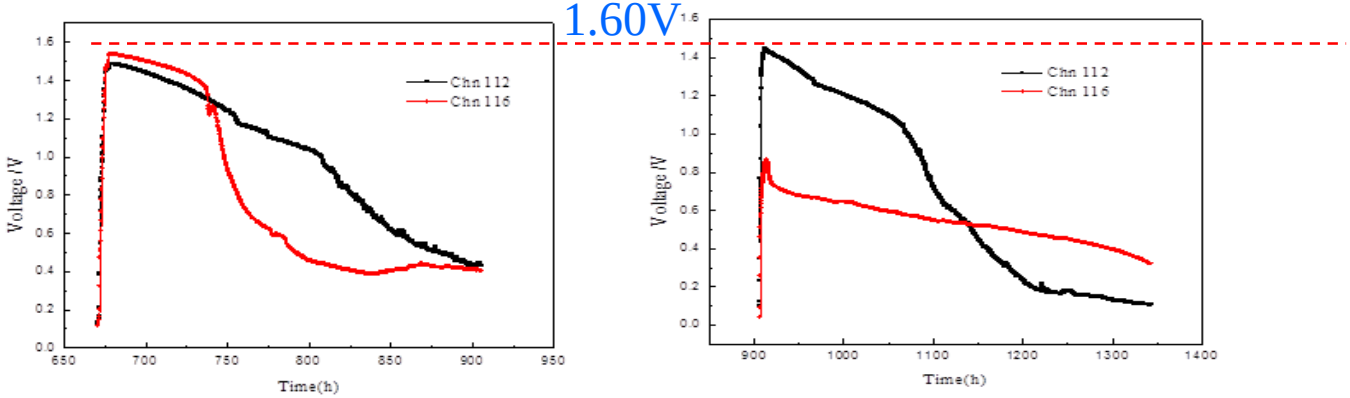


- **A novel graphene/riboflavin (RF) composite electrode was developed, the graphene/RF electrode greatly decreased charge transfer over-potential, which in turn delivered about 5.3 and 2.5 times higher power output than that by bare graphite paper electrode and graphene electrode, respectively.**

Electricity generation by MFC using anaerobic digestion slurry



The highest voltage topped at 0.65 V with single MFC.



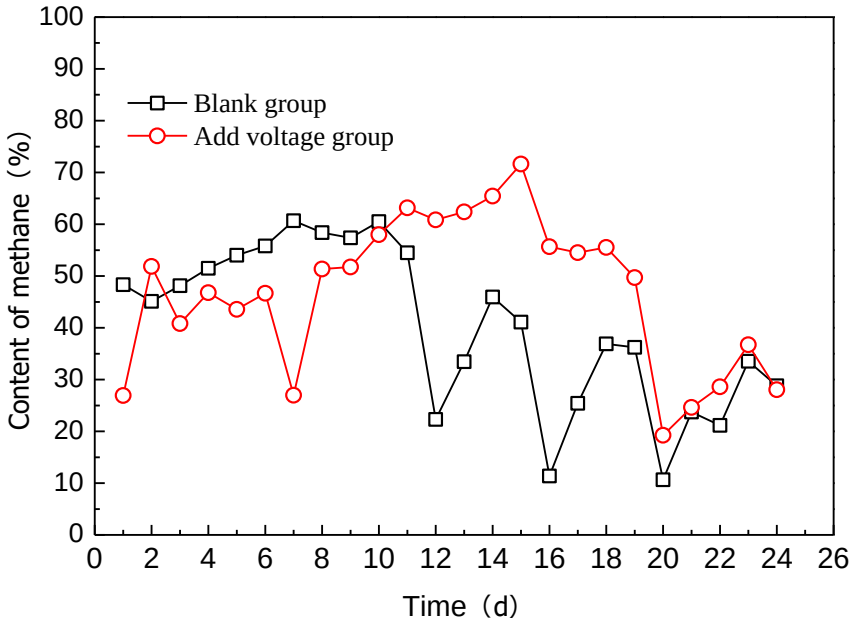
The highest voltage topped at 1.6 V with tandem MFC.

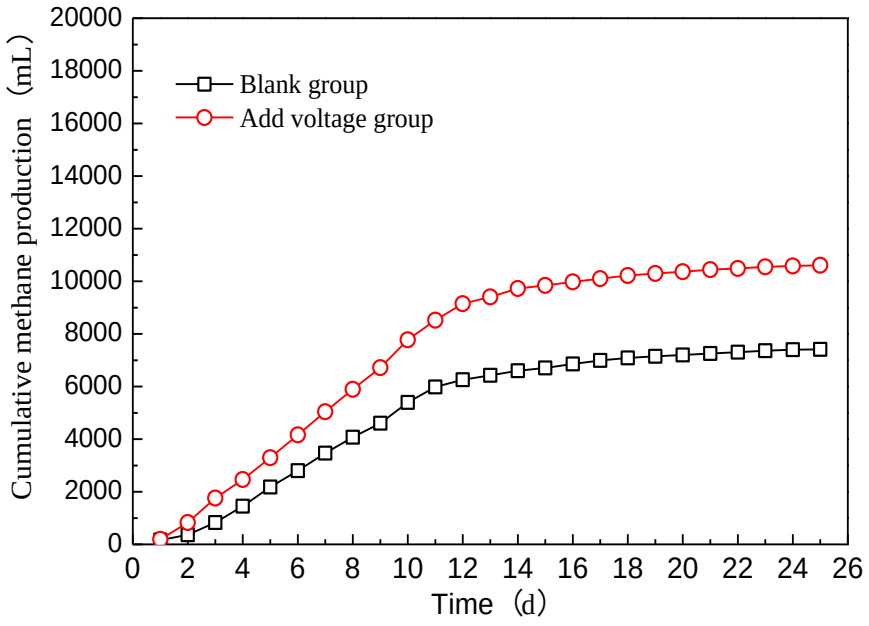
Electricity generation by MFC using anaerobic digestion slurry

Batch	COD/mg·L^{-1}	Removal rate	NH_3^+-N /mg·L^{-1}	Removal rate	P/mg·L^{-1}	Removal rate
material	7404±165		2708±78		92.19±11	
One	2206±68	70.21±1.34%	508±22	81.24±0.99%	26.72±6	71.02±1.68%
Two	2119±75	71.38±0.98%	405±19	85.04±0.85%	22.16±3	75.96±2.16%
Three	1912±56	74.18±2.13%	359±16	86.74±1.03%	20.68±5	77.57±1.97%
Four	1765±58	76.16±1.56%	373±12	86.22±0.78%	21.65±5	76.51±1.66%
Removal rate		72.98±1.48%		84.81±0.90%		75.27±1.68%

- **MFC can remove a great deal of COD, nitrogen, and phosphorus in anaerobic digestion slurry.**

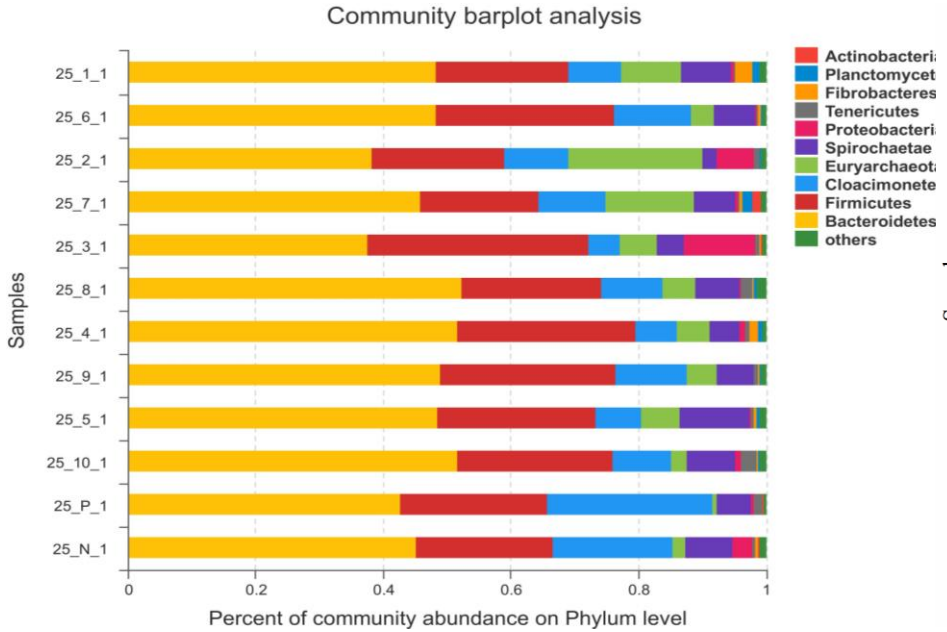
Anaerobic digestion combined with MFC system

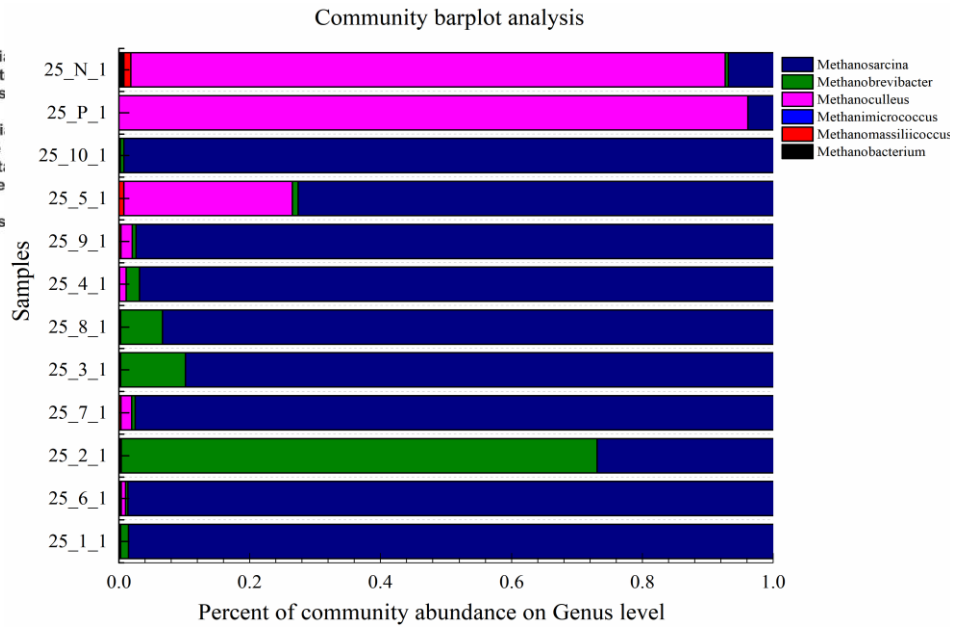




- **Total biomethane production increased by 43.47% compared with the control.**

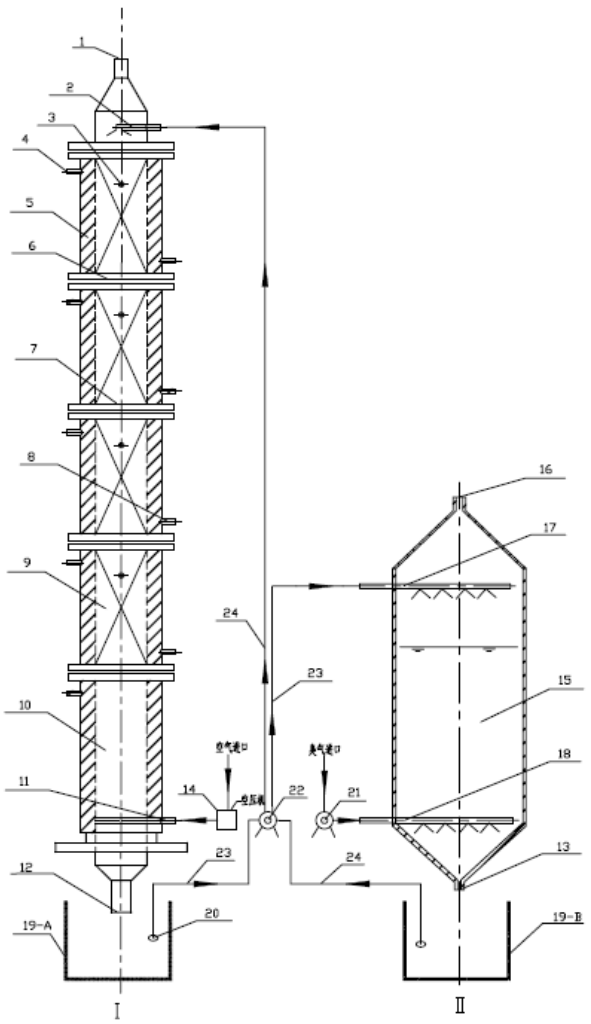
Anaerobic digestion combined with MFC system





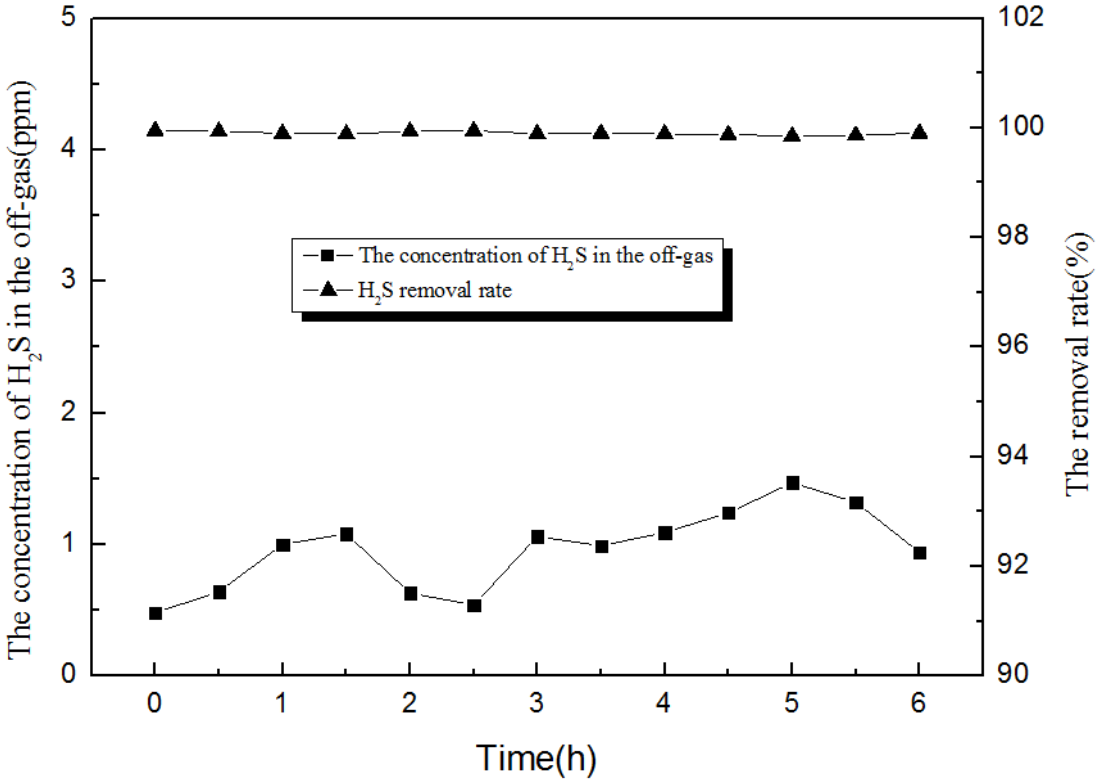
- **High-throughput sequencing analysis indicated that the dominant species at phylm level were Bacteroidetes and Firmicutes in AD of swine manure.**
- **The dominant methanogens were *Methanosarcina* and *Methanobrevibacter* in voltage group whereas those in control was *Methanosarcina*.**

Biogas desulfurization



Biooxidation reactor

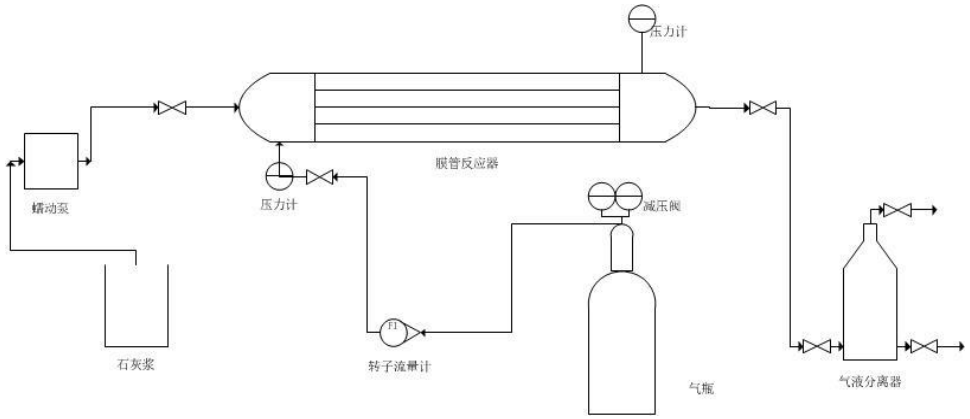
Chemical absorption reactor

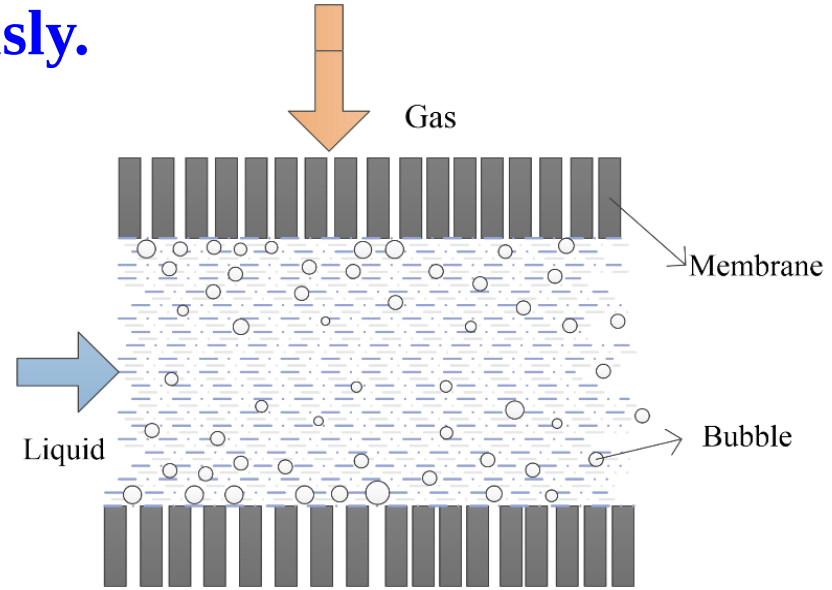


- **99% of H_2S can be removed by biooxidation combined with chemical absorption reactor.**

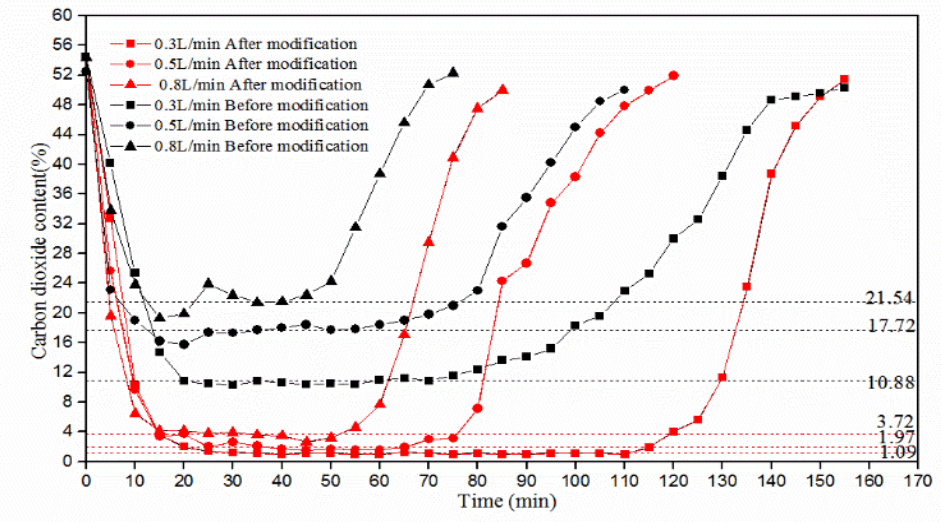
Biogas upgrading

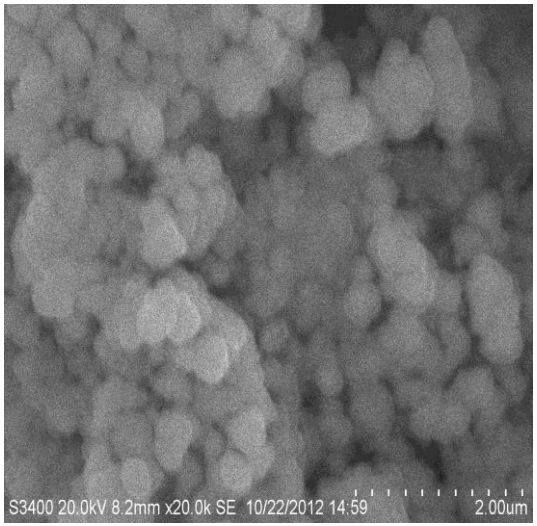
- **Biogas purification and nanoscale $CaCO_3$ synthesis in a membrane reactor simultaneously.**





Biogas upgrading

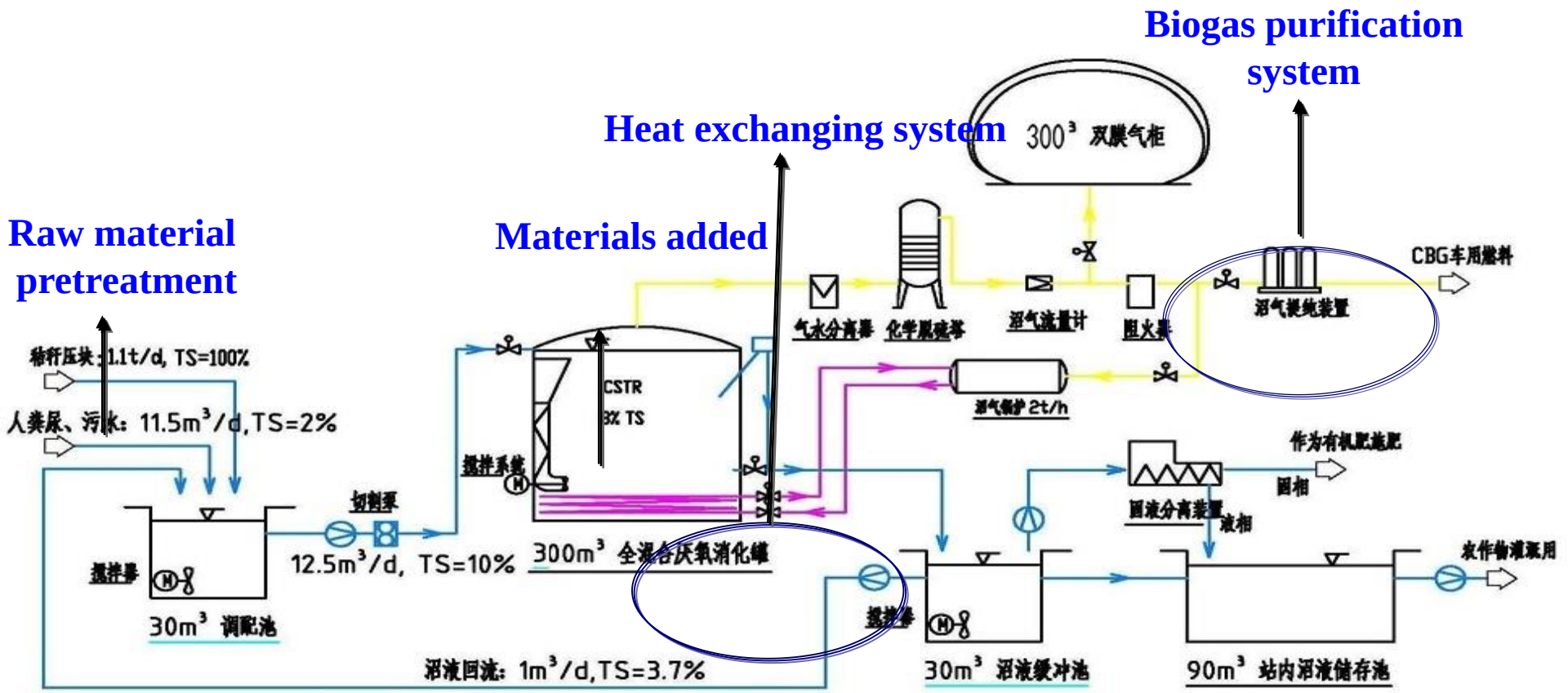




- **The methane content can be lifted to more than 97%, meanwhile produced nanoscale calcium carbonate with 72.8 nm average particle size.**

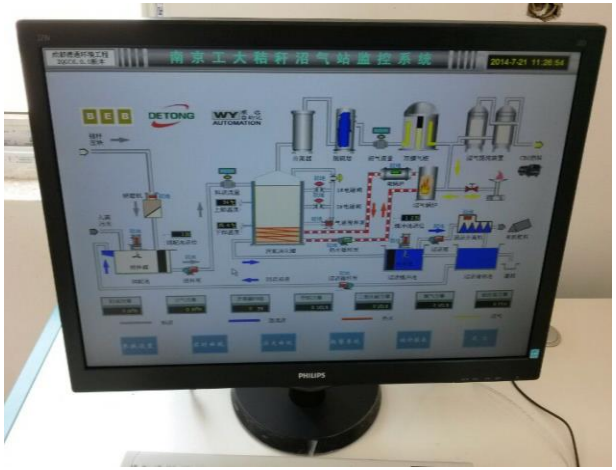
3. Commercial projects

Biogas demonstration project in NanjingTech



Biogas demonstration project in Nanjing Tech

Anaerobic digester and gas storage



Online control system

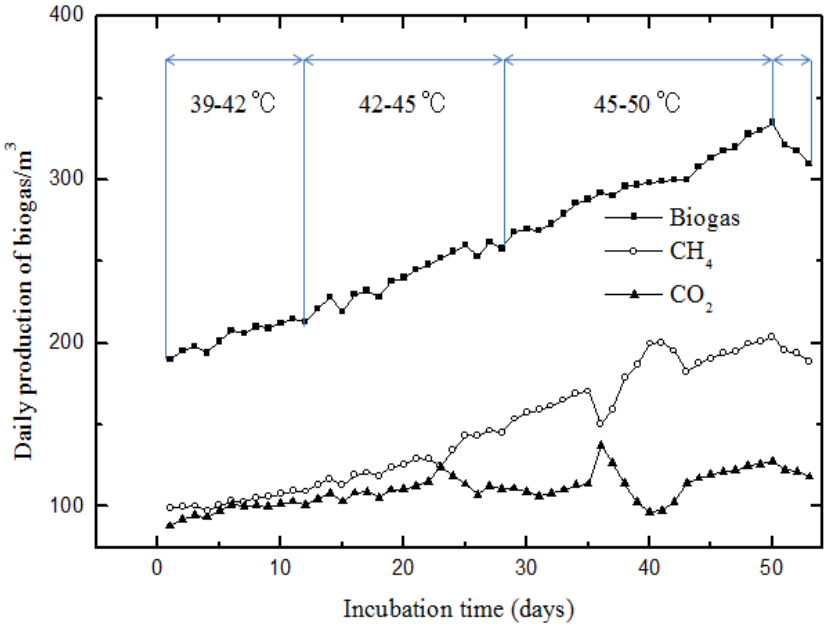
Heat exchanging system

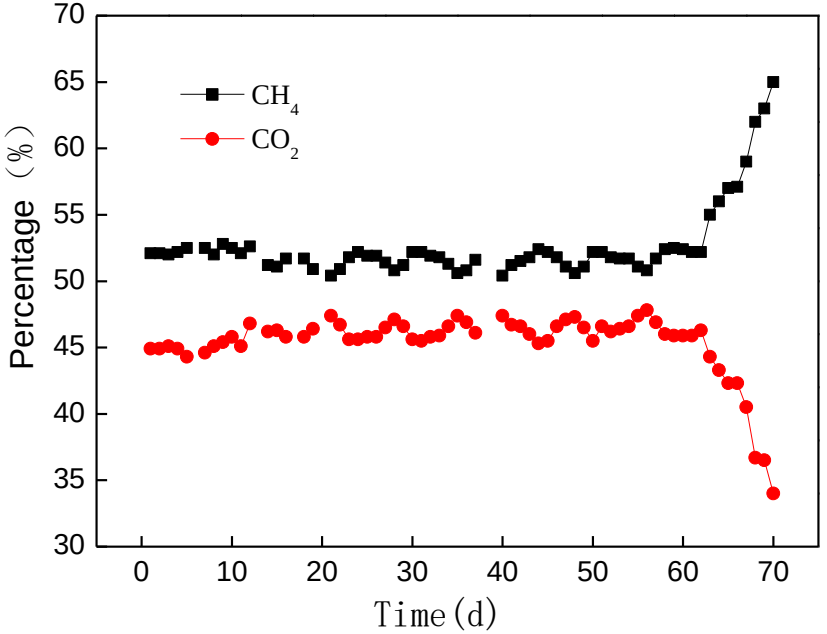
PSA

Biogas slurry dewatering system

Biomethane car in Nanjing Tech

Biogas demonstration project in Nanjing Tech





- **At 39 °C, the methane content was 53% and volumetric biogas production was 0.86 $m^3/m^3 \cdot d$ in a 300 m^3 anaerobic digester.**
- **At 50 °C, the methane content and volumetric biogas production were 65% and 1.1 $m^3/m^3 \cdot d$ respectively with 65% of conversion of straw and a yield of 400 m^3 per ton of straw.**

Biogas project in Nanyang, Henan province

Raw materials	Digester volume	Feeding	TS	Biogas capacity	Temperature	Biogas utilization	Founded year
Corn Straw	3,500 m^3	100 t/d	10%	6,000 m^3/d	42 ºC	CHP	2015

Biogas project in Dafeng, Jiangsu province

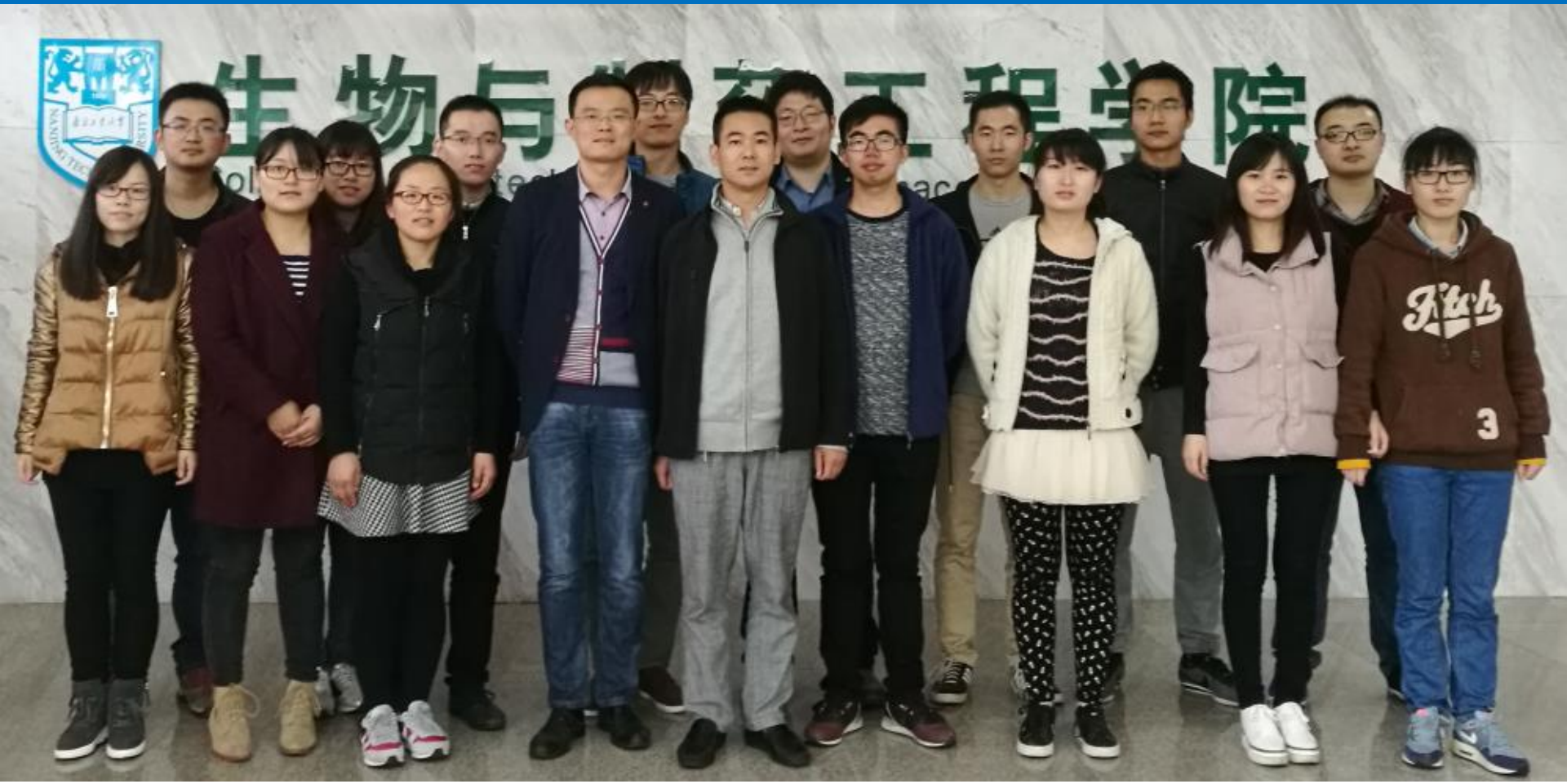
Raw Material	Digester volume	Feeding	TS	Biogas capacity	Temperature	Founded year
Chicken manure	20,000 m^3	500 t/d	10%	20000 m^3/d	38 °C	2014

Conclusions

- **Converting agro-waste to biomethane is a sustainable way for China.**
- **The technology for agro-waste pretreatment and biogas upgrading was developed in Nanjing Tech University.**
- **A biomethane demonstration project has been operated in our campus since 2014.**
- **Some our technologies are testing in several biogas projects in China now.**

Acknowledgements

- **The European Union Horizon 2020 Research Innovation Program and MOST**
- **National Natural Science Foundation of China**
- **National Key Basic Research Program of China**
- **Nation Key Technology Support Program of China**
- **Other Financial Supports from MOE and Jiangsu Province**



Thank you
for your attention!