Optimizing mixing time to lower the energy consumption of an anaerobic digestion waste-to-energy system for food waste management

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ANAEROBIC DIGESTION WTE

Collection & Sorting

Dry wastes

Incineration & Gasification

Agricultural Waste

Waste

Anamial Manure

Horticultural Waste

Wastewater

Building

Electricity

Biogas

Fertilizer

Cooling

Anaerobic Digestion

Digestate

Chiller

Engine Generator

Waste Heat Recovery

CHALLENGES AND DEMANDS FOR FOOD WASTE TREATMENT

Chellenges

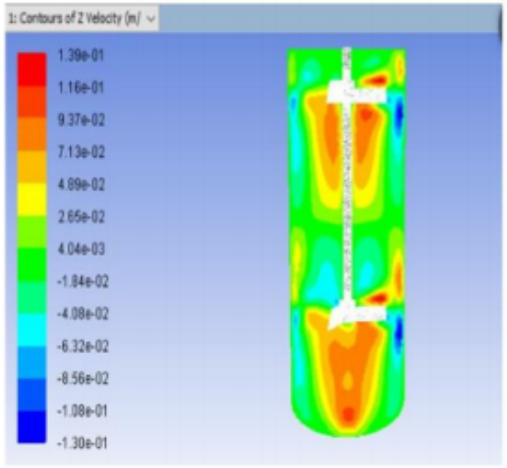
- **Waste sorting**
- **Sensitive**
- **Energy Intensive**
- **Low energy recovery**

Demands

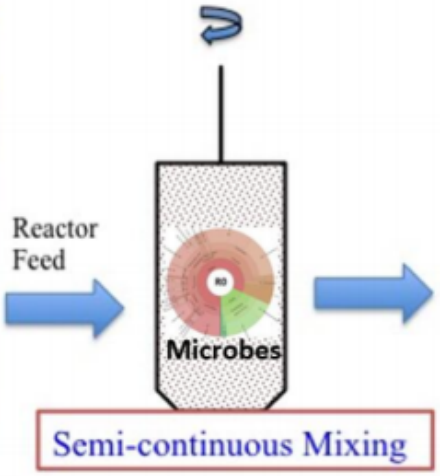
- **High sorting efficiency**
- **High treatment capacity**
- **Low energy consumption**
- **Efficient energy recovery**

Optimizing mixing in Anaerobic digester ?

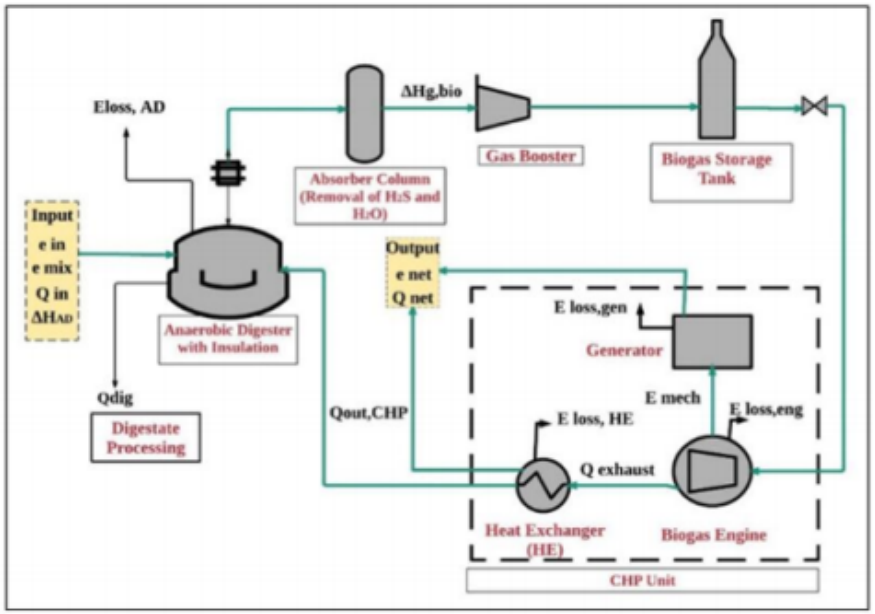
OPTIMIZATION OF MIXING TIME IN AD



CFD simulation



Optimizing mixing time



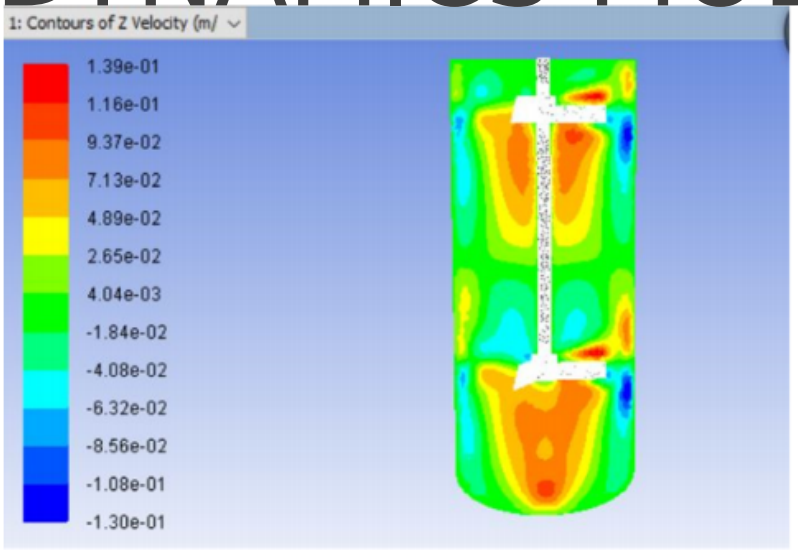
Lower Energy Consumption

FOOD WASTE

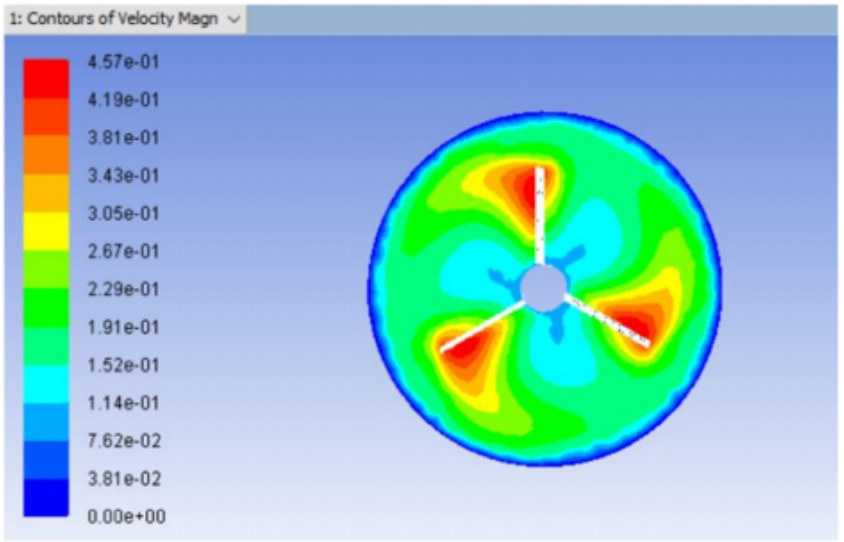
Table 1
Characteristics of food waste.

Components	Unit	This Study	Other Studies	
			Zhang et al. [14]	Banks et al. [15]
Total Solids	wt %	31.70 ± 1.20	30.90	23.74
Volatile Solids	wt %	29.59 ± 2.37	26.35	21.71
VS/TS	wt %	93.34 ± 1.54	85.30	91.44
Non-Metals		This Study		Han and Shin [16]
Carbon	wt %	47.08 ± 2.01	46.78	51.40
Hydrogen	wt %	7.04 ± 1.11	–	6.10
Nitrogen	wt %	3.02 ± 0.32	3.16	3.50
Sulphur	wt %	< 0.5	–	1.00
C/N ratio	–	15.58 ± 1.87	14.80	14.69
Metals			El-Mashad and Zhang [17]	
Al	wt %	< 0.01	0.054	
Ca	wt %	0.17 ± 0.10	–	
Cu	wt %	< 0.01	0.001	
Fe	wt %	< 0.01	0.072	
K	wt %	0.37 ± 0.06	0.795	
Mg	wt %	0.04 ± 0.01	0.161	
Mn	wt %	< 0.01	0.005	
Na	wt %	0.86 ± 0.45	–	
Zn	wt %	< 0.01	0.006	

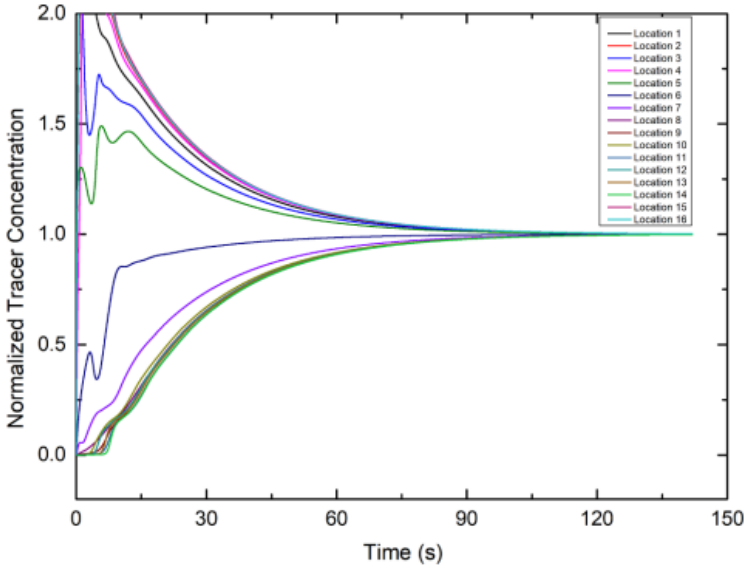
COMPUTATIONAL FLUID DYNAMICS MODELING



(A)



(B)



Optimum Mixing Time – 2 mins/hour

STATISTICAL ANALYSIS OF PROCESS PARAMETERS

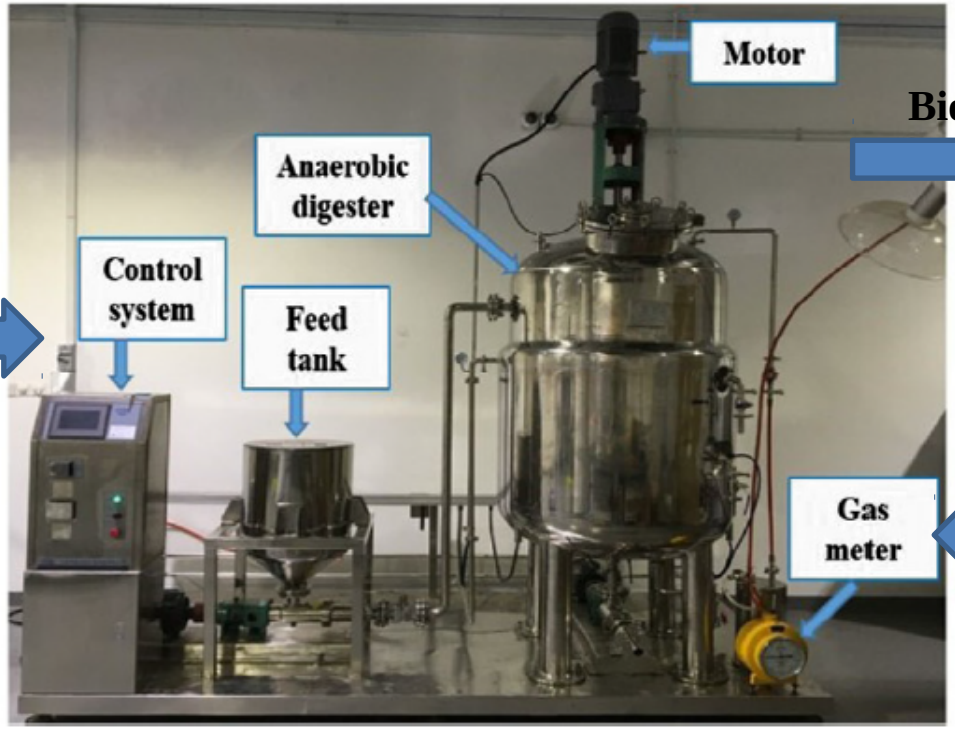
Components	R1	R2	R3
1–10 days – 0.9 g VS/L/day			
SMP[a] (ml CH_4/gVS/d)	377 ± 36	387 ± 30	262 ± 27
pH	7.3 ± 0.2	7.2 ± 0.1	7.1 ± 0.2
COD (mg/L)	712 ± 59	737 ± 39	722 ± 47
VFA (mg COD/L)	305 ± 29	321 ± 47	307 ± 39
TS (wt %)	2.1 ± 0.3	2.1 ± 0.2	2.0 ± 0.2
11–20 days – 1.8 g VS/L/day			
SMP[a] (ml CH_4/gVS/d)	423 ± 40	398 ± 33	270 ± 26
pH	7.3 ± 0.1	7.2 ± 0.2	6.2 ± 0.2
COD (mg/L)	1223 ± 43	1037 ± 98	1563 ± 102
VFA (mg COD/L)	615 ± 59	587 ± 86	831 ± 91
TS (wt %)	2.2 ± 0.2	2.2 ± 0.3	2.1 ± 0.3
21–30 days – 2.4 g VS/L/day			
SMP[a] (ml CH_4/gVS/d)	437 ± 26	396 ± 27	89 ± 12
pH	7.1 ± 0.1	7.1 ± 0.2	5.6 ± 0.2
COD (mg/L)	1613 ± 109	1737 ± 87	4309 ± 213
VFA (mg COD/L)	1009 ± 93	1127 ± 129	2890 ± 426
TS (wt %)	2.5 ± 0.2	2.3 ± 0.2	2.4 ± 0.4

[a] Values are expressed as mean ± standard deviations.

Semi-continuous mixing mode is preferred !

FOOD WASTE AD SYSTEM

Food Waste



Anaerobic Digestion System

Biogas

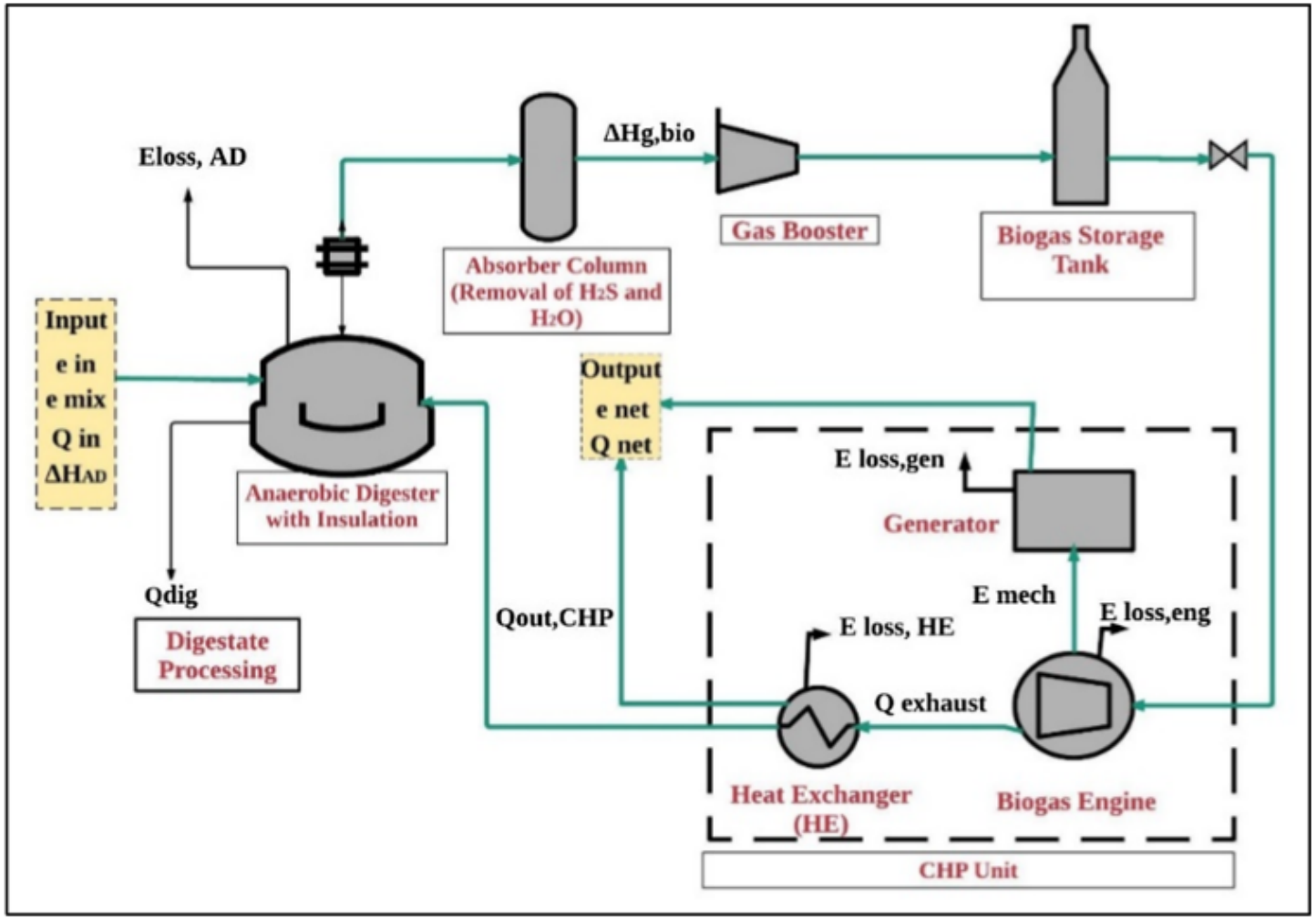
Combined Heat and Power System

Electricity and heat

Recovery

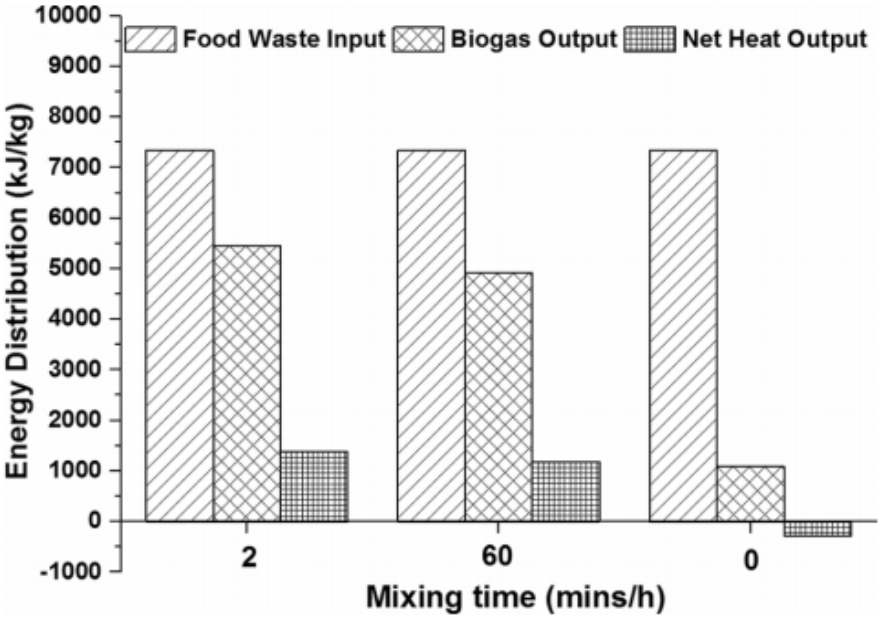
Net energy output

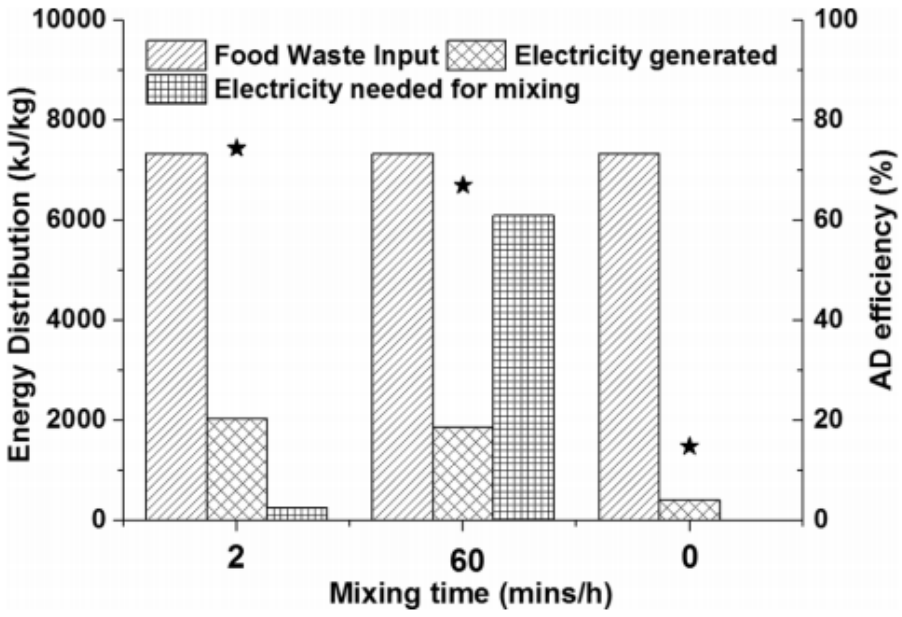
ENERGY FLOW CHART



CHP - Combined heat and power unit

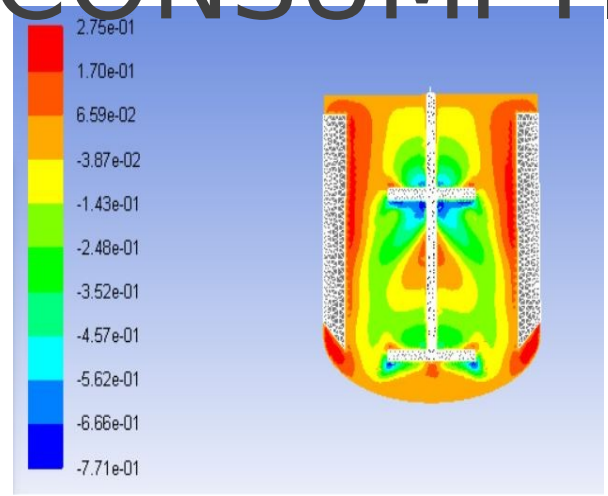
ENERGY PERFORMANCE



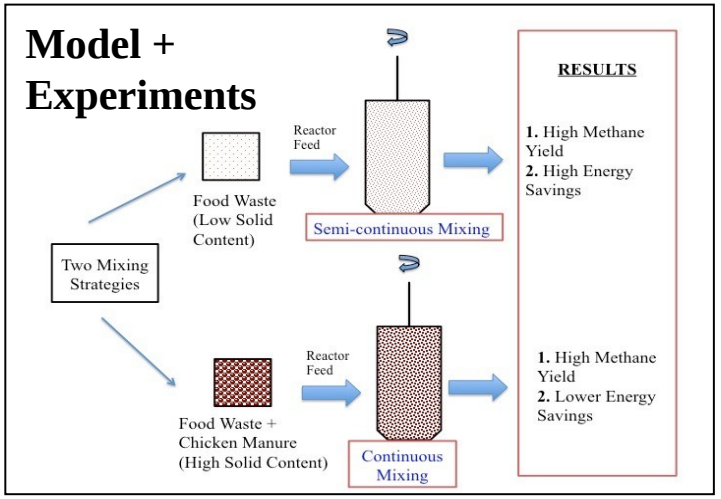


Net energy output is achieved in semi-continuous mixing mode

REDUCING ENERGY CONSUMPTION



Computational Fluid Dynamics (CFD) modelling for mixing



Semi-continuous mixing strategy

Different Scales of Engine Generator systems

APPLICATIONS IN SINGAPORE

☐ Demonstration of NUS-SJTU in Singapore

Anaerobic digestion waste-to-energy eco-system for food waste in Raffles Hall Canteen

Treatment Capacity: 50-200 kg/day

Reactor volume: 1 m^3

Location: Opposite Raffles Hall Canteen

Output: Electricity, Heat and fertilizer

Container: 20 feet

NUS Frontier Phase Canteen

CONCLUSIONS

- Energy consumption for AD systems can be optimized
- Reduction through mixing time and process parameters
- Combination of CFD modeling and experimental validation in pilot-scale systems

NUS National University of Singapore

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