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Effect of oil content on biogas production and performance stability of anaerobic digestion of food waste

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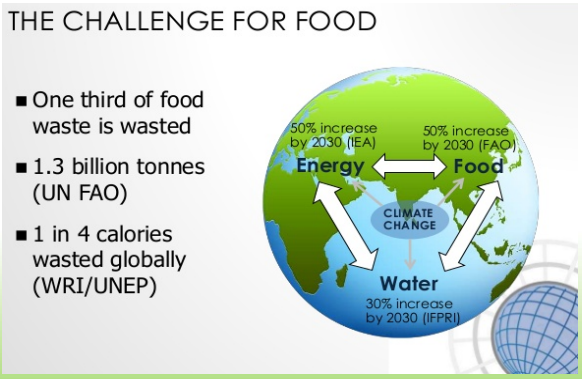
Presentation Outlines

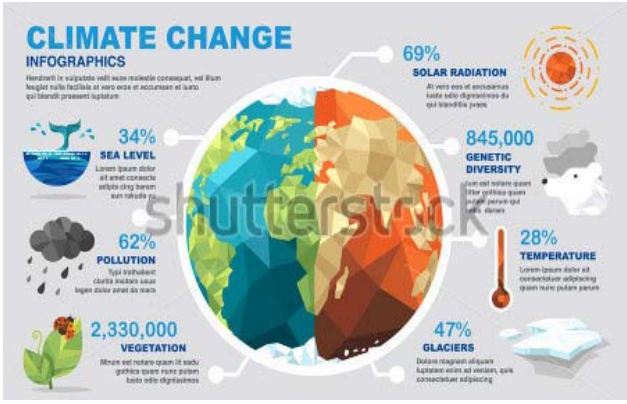
1. Introduction and background information
2. Food waste compositions
3. Problem of Lipid fraction of Food Waste
4. Food waste challenges
5. Research Objectives
6. Materials & Methods
7. Results & Discussion
8. Conclusions

Introduction & challenges Food Waste

The key drivers:

Environmental consequence of waste generation



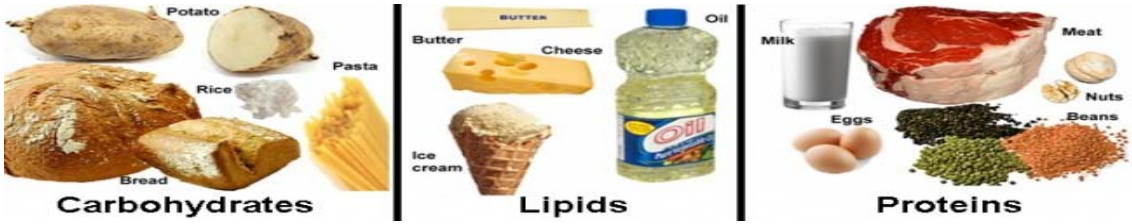


GHG emission on landfill

Soil & ground water pollution

Municipal Solid Wastes & FW Compositions

Three Broad Categories:



- The biodegradability or hydrolysis rate differs; Lipids < Proteins < carbohydrates.
- Proteins and carbohydrates decomposed faster and can be used than oil (lipids). Lipids degradation is seen as a rate limiting step for Food Waste Anaerobic Digestion.
- Chinese FW different from Food Waste other countries - due to dietary habit in China
- Lipids (23-31%), protein (15-28%), and carbohydrate (22-27%)

FW account for 25 – 45 % MSW in countries

Chinese food waste rich in salt & oil

Municipal oil waste challenges

- Total Solid of oil 1 – 2%,
- Not suitable for incineration & landfills
- Too wet for efficient composting or mono AD
- high lipids conc. & production of (LCFAs), etc

Lipid 1.425 g/L (CH_4 of 69.5%),

proteins 0.921 g/L (CH_4 of 68.8%)

carbohydrates 0.830 g/L (CH_4 of 50%)

Kitchen oil waste

Sewer blockage in UK costing €20m

Consequence of dropping oil in sewer

Research Objectives

- To investigate the effect of oil addition on the process performance and stability of the digesters.

- Effect of oil addition on different OLRs

- Effect of oil addition 'on:' NH_4^+, alkalinity, tVFA, FOS/TAC, and pH

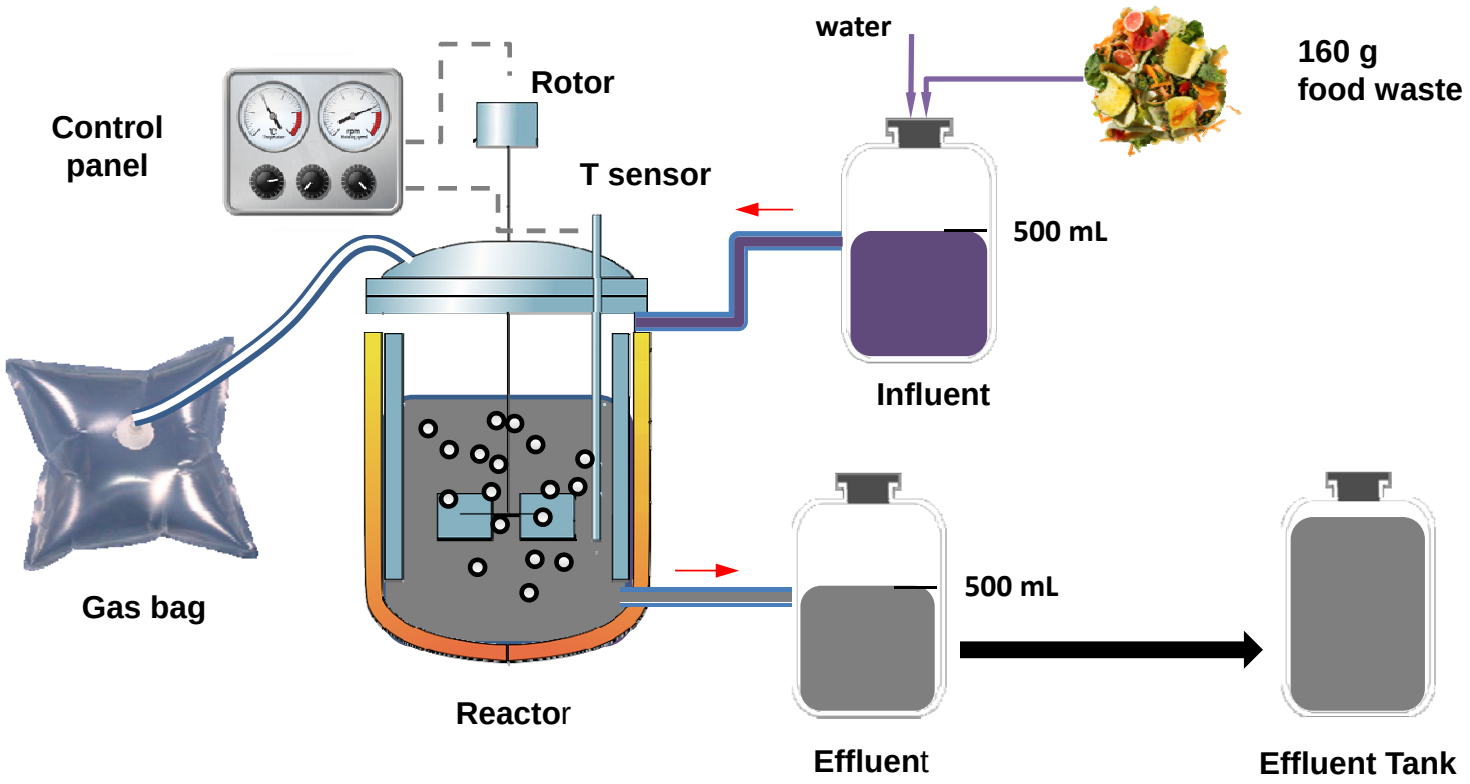
- Effect of oil addition on; TS (reduction efficiency), VS (destruction efficiency), and TCOD (removal efficiency)

- Effect of oil addition on; the biogas production and CH_4 yield

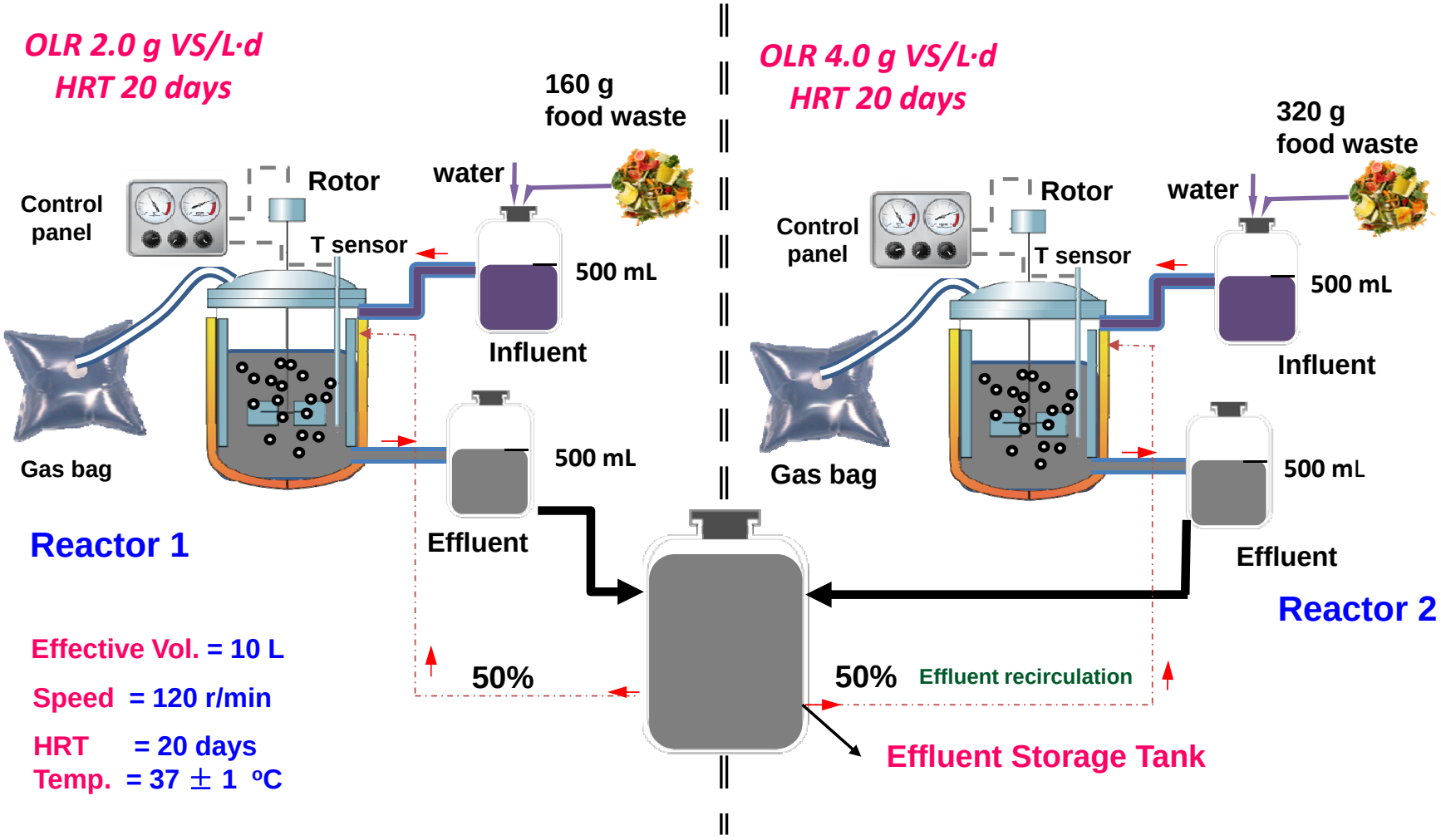
Materials & Methods

Substrates	Sources	Pre-treatments
Food waste	School restaurant	Removal of impurities, dilution & blending to homogenized it. Stored at 4 °C prior to use or -10 °C for later use.
Oil	School restaurant, supermarket	Stored at room temp (25 °C) prior to use
Inoculum (digested sludge)	Pig manure AD plant (20L)	Incubated at 35 °C and stored at 4 °C

Experiment Design & Set up



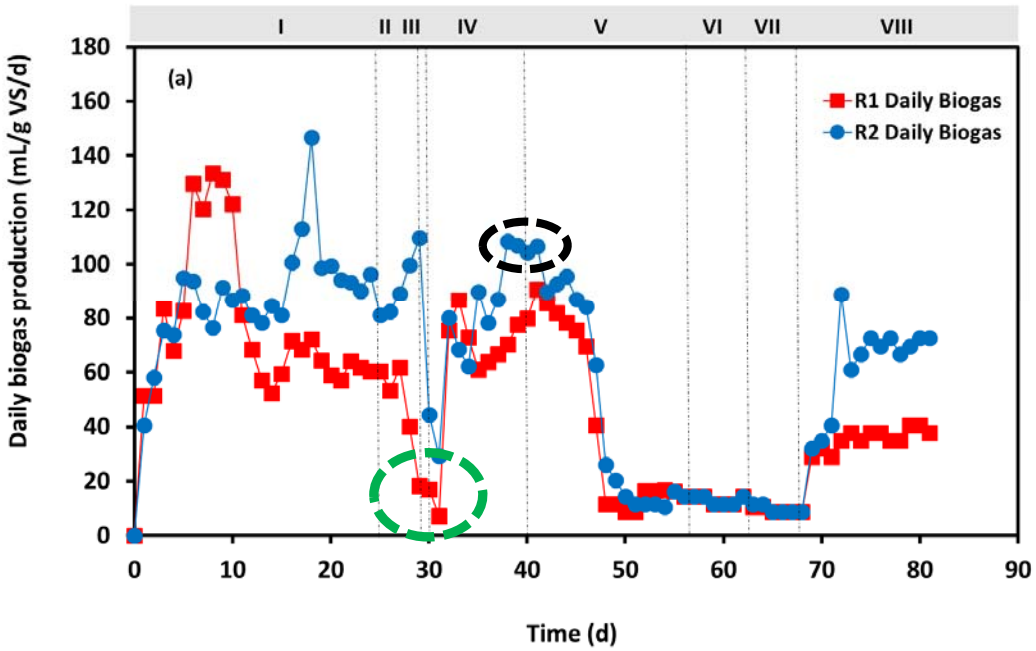
Schematic diagram of laboratory-scale setup for two CSTR reactors

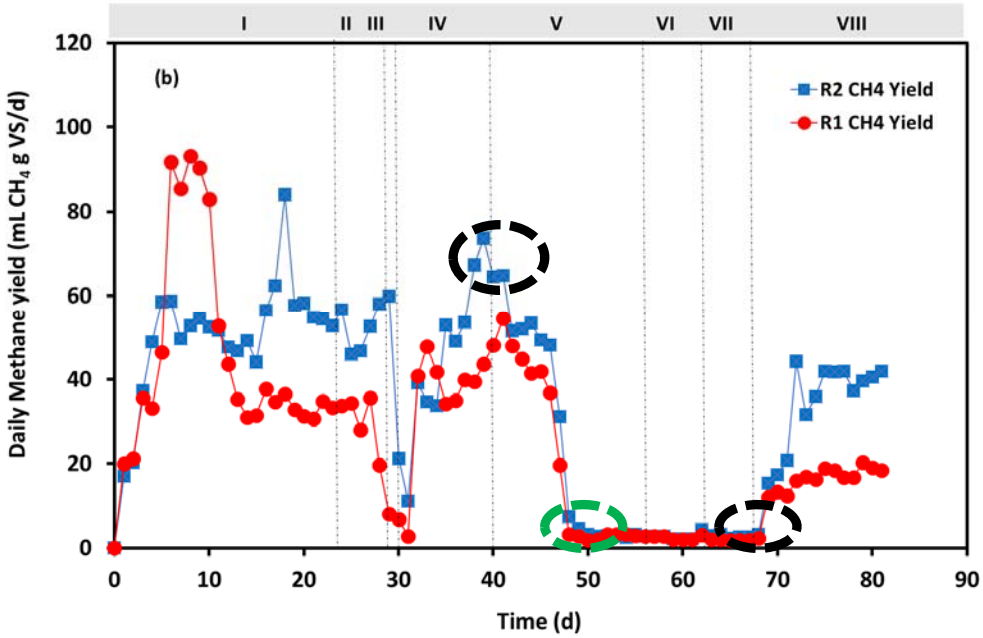


Results and Discussion

Effects of oil addition on daily Biogas productions & Methane yields

Experimental Stages





Phase I (0-25) - FW with 2.0 g VS(L/d), 4.0 g VS(L/d) OLRs

Phase II (25-29) 5 % oil content based OLRs added

Phase III (29-30) oil addition stopped-(R1) 2.0 g VS(L/d) failed

Phase IV (30-40), R1 OLR increased to 4.0 g VS (L/d)

Phase V (40-57) 5% oil content was added again

Phase VI (57-63) NaOH was added

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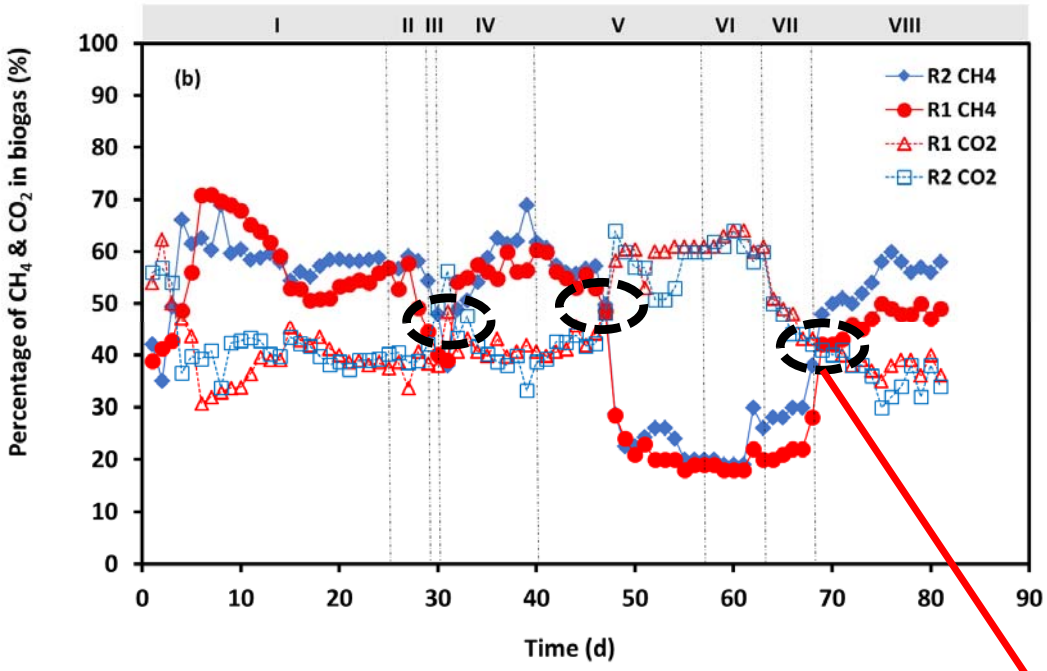
Effects of oil addition on daily Biogas compositions & TCOD

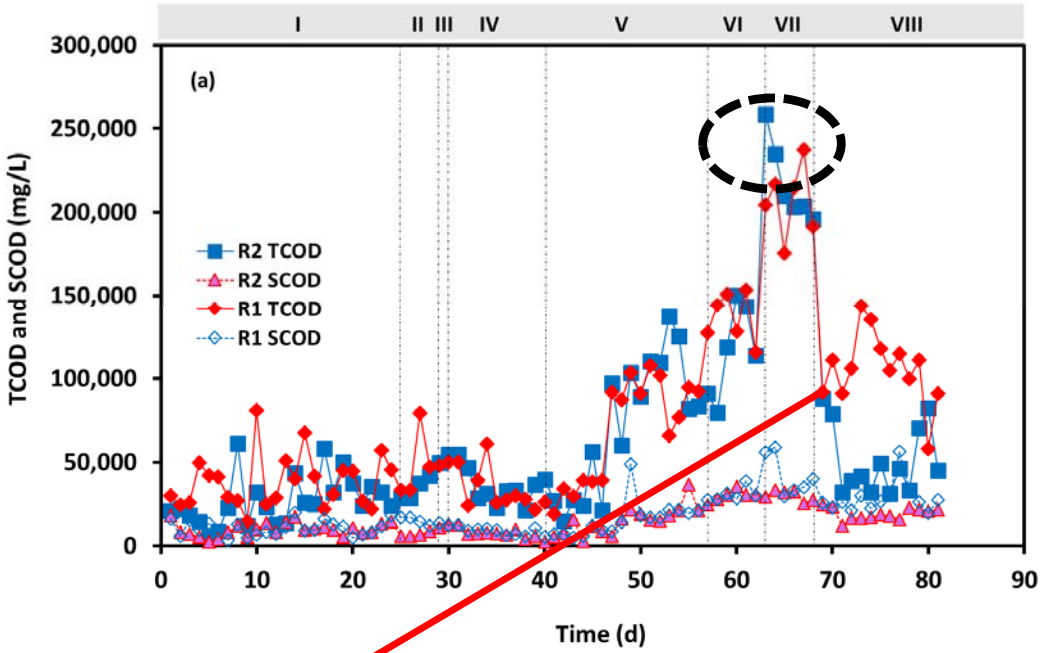
Experimental Stages



Phase VII (63-68), feeding stopped on R2 & R2, for five days

Phase VIII (68-90), 50% recirculation of effluent for R1 & R2

Results & discussion



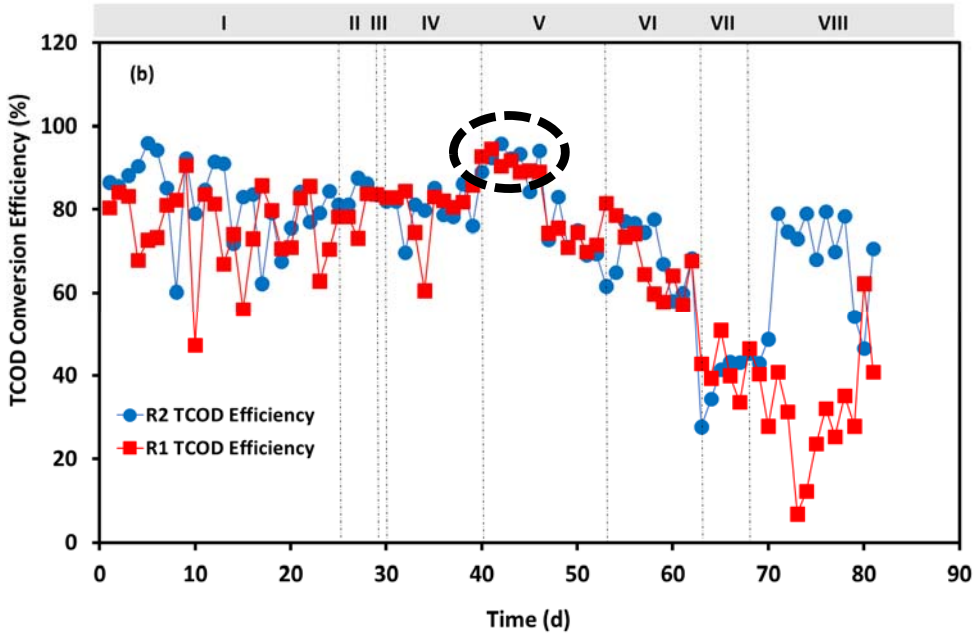
TCOD Conversion efficiency can dictate the reactors performance

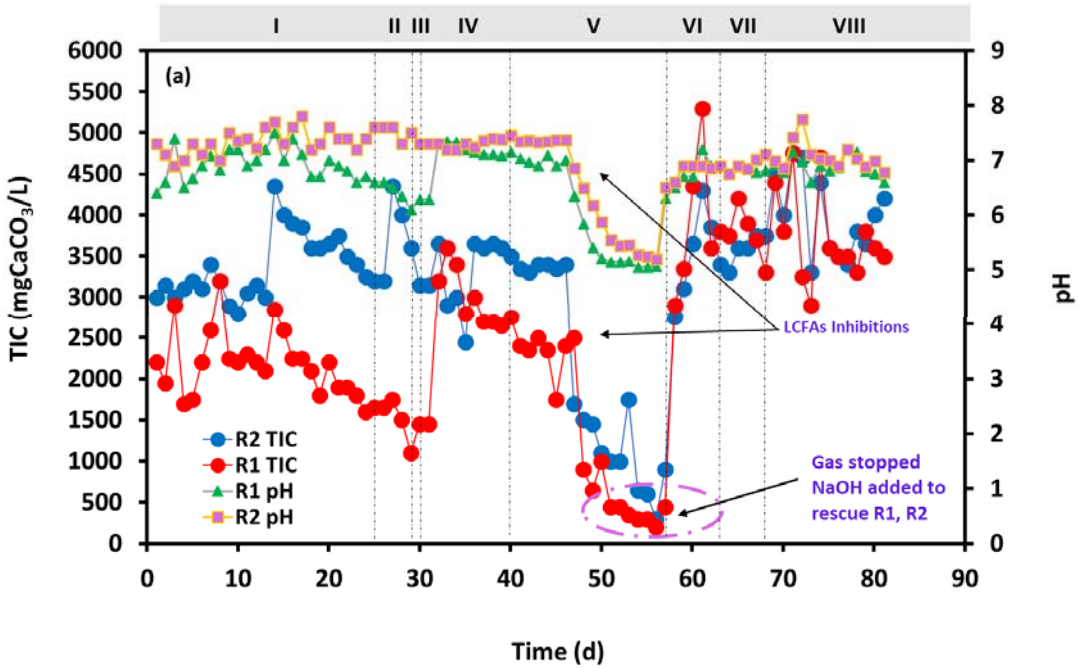
The lower the TCOD Conversion efficiency, the lower the biogas produced

	TS (%)	VS (%)	VS/TS (%)	SCOD (mg/L)	TCOD (mg/L)	NH_4^+-N (mg/L)	TIC mg/L$CaCO_3$	TVFA (mg/L)	FOS/TOAC
Inoculum	4.64	3.04	65.56	7,000	38,750	2107	4,300	364	0.08

Effects of oil addition on TCOD conversion efficiency & Alkalinity

Results & discussion





TCOD conversion efficiency peaking at 95% for R1 and 94% for R2

Effluent quality changed with reactor's performance:

- **High TCOD due to non-conversion of substrate due to high VFAs Conc.**
- **High viscosity and odour**
- **Milky colour & foaming**

TIC (R1), reduced from 2750 mg/L $CaCO_3$ to 200 mg/L $CaCO_3$, (92.73%).

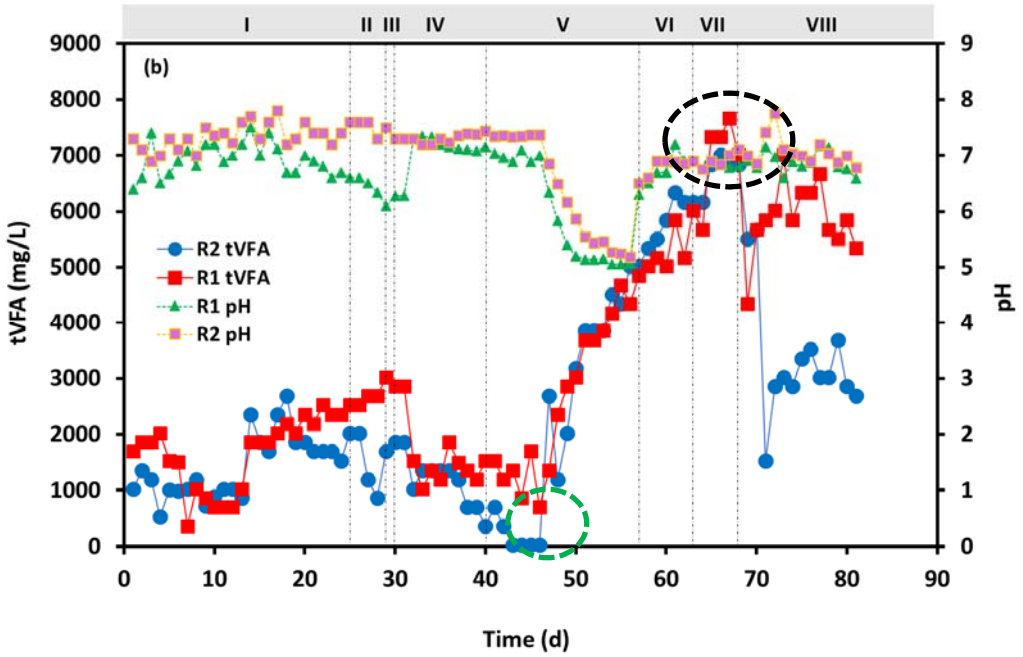
R2, reduced from 3500 mg/L $CaCO_3$ to 300 mg/L $CaCO_3$ (91.43%)

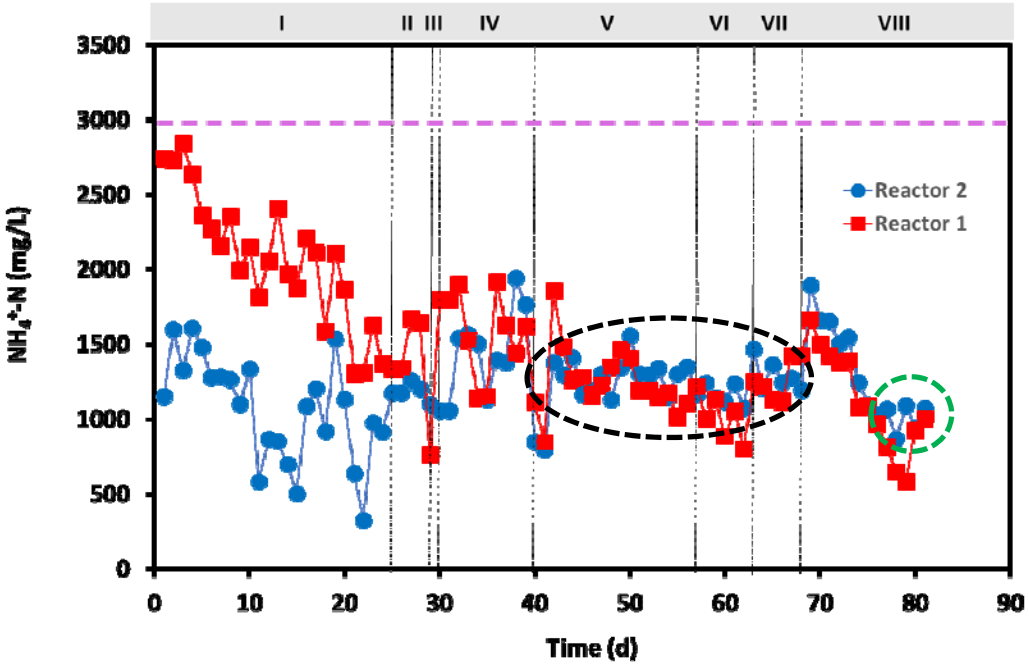
TIC increased from 200 mg/L $CaCO_3$ to 5,300 mg/L $CaCO_3$ (96.23%)

TIC increased for R2, from 300 mg/L $CaCO_3$ to 4,300 mg/L $CaCO_3$ (93.02%)

Effects of oil addition on pH, tVFAs & Ammonia Nitrogen

Results & discussion





There was gradual reduction in the conc. of VFA from 6838 mg/L before recirculation to 2854 mg/L, 7 days after recirculation.

NH_4^+-N has been relatively stable even after the addition of 5% oil contents.

NH_4^+-N ranging between 805 mg/L to 1404 mg/L for R1 and, 797 mg/L to 1558 mg/L for R2

This study, NH_4^+-N conc. fell in the range of 770-2748 mg/L for R1, and 325-1600 mg/L for R2,
Lower than the critical NH4+-N conc. of 3000 mg/L.

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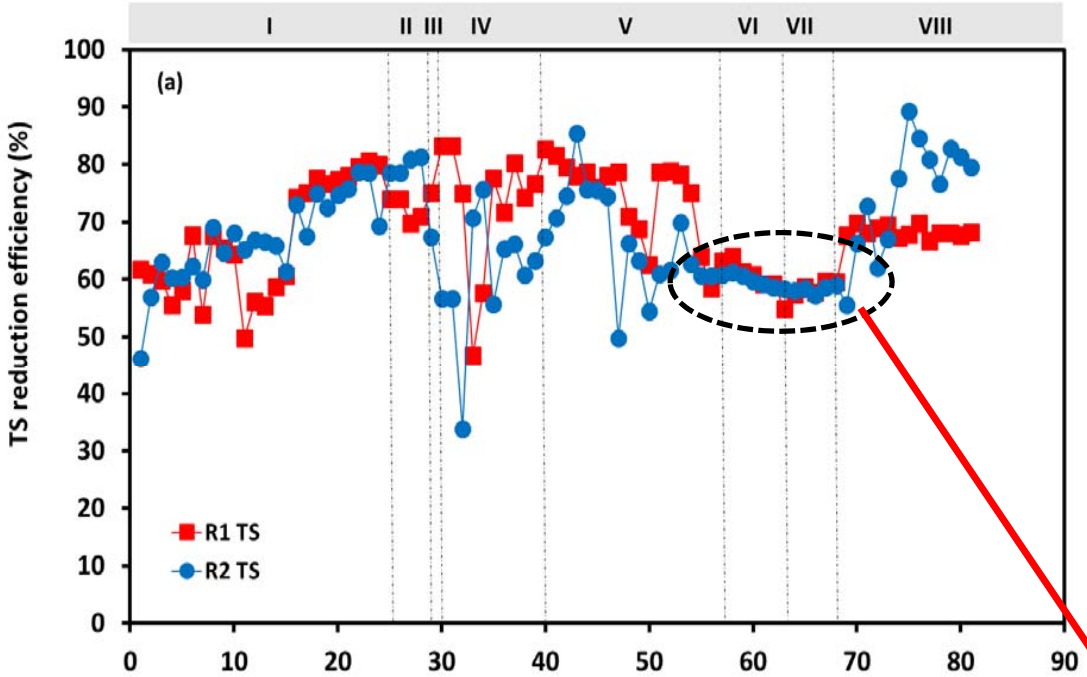
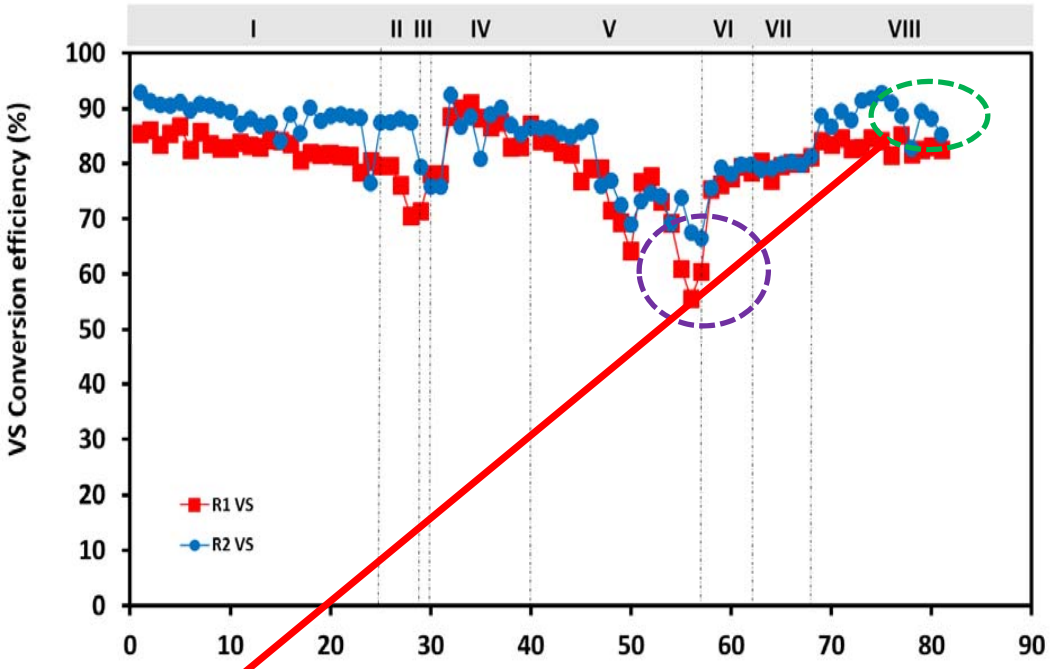
Effects of oil addition on TS reduction, VS conversion efficiency

Strangely, 60% (R1) & 67% (R2) VS destruction efficiency does not translate into biogas production?

TS reduction of 63% (R1) & 61% (R2) only result in high viscosity!



TS reduction efficiency



VS conversion efficiency

	TS (%)	VS (%)	VS/TS (%)	SCOD (mg/L)	TCOD (mg/L)	NH_4^+-N (mg/L)	TIC mg/L$CaCO_3$	TVFA (mg/L)	FOS/TOAC
Inoculum	4.64	3.04	65.56	7,000	38,750	2107	4,300	364	0.08

Conclusion

- There was gradual reduction in the concentration of VFA from 6838 mg/L before recirculation to 2854 mg/L, 7 days after recirculation.
- And in this study, NH_4^+-N concentration fell in the range of 770-2748 mg/L for R1, and 325-1600 mg/L for R2, which is lower than the critical NH_4^+-N concentration of 3000 mg/L.
- Ammonia was not a key inhibiting factor of FW throughout this study.
- Lipids inhibitions and other operational challenges of oil addition to FW could be overcome with; combination of NaOH addition coupled with recirculation of certain percentage of the digester's effluent, to kick-start dilution and breaking the LCFAs accumulations and reduced high VFA concentration
- This study provided understanding of the dynamic complex nature of Chinese food waste, especially because of it high salinity and lipids contents.

THANK YOU!