

WWW-YES-2011 France

Anaerobic Co-digestion of Brown Water and Food Waste for Energy Recovery

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<http://www3.ntu.edu.sg/r3c/>

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Singapore

Housing Development Board (HDB) Flats



Residues and Resource Reclamation Centre (R3C)

Established in May 2009 to spearhead research efforts in developing sustainable waste management technologies

Core Capabilities

• **Waste to Materials**

- Converting wastes into new and useful materials (e.g., plastic waste into biodegradable PHA polymer, incineration bottom ash into stabilized carbonated ash product for high value usage, etc.)

• **Waste to Energy**

- Harnessing energy from urban biomass, sewage sludge, agricultural residues, micro-algae, etc.

• **Contaminated Site Remediation**

- Develop solutions and technologies for remediating contaminated sites



Plastic waste →

to PHA



Ashes to →

construction material



Food waste plant for biogas production



Rooftop microalgae cultivation for biofuel production

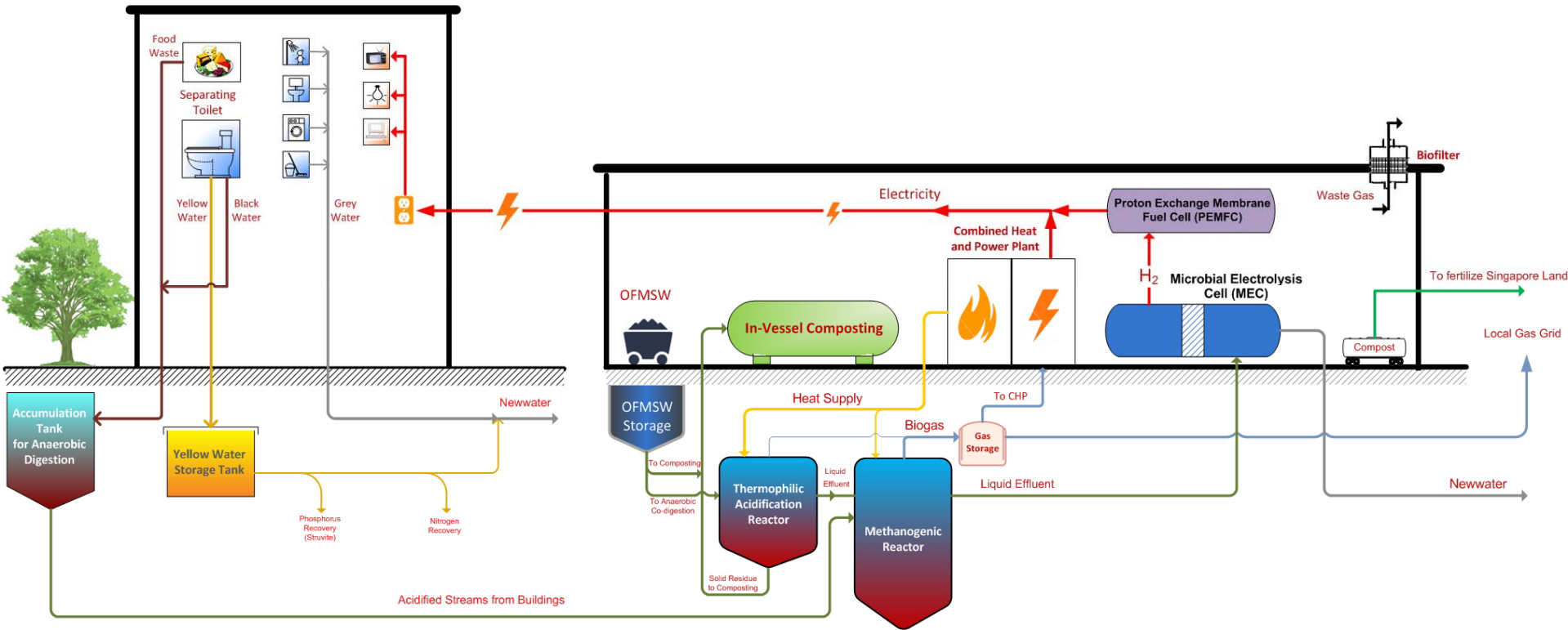
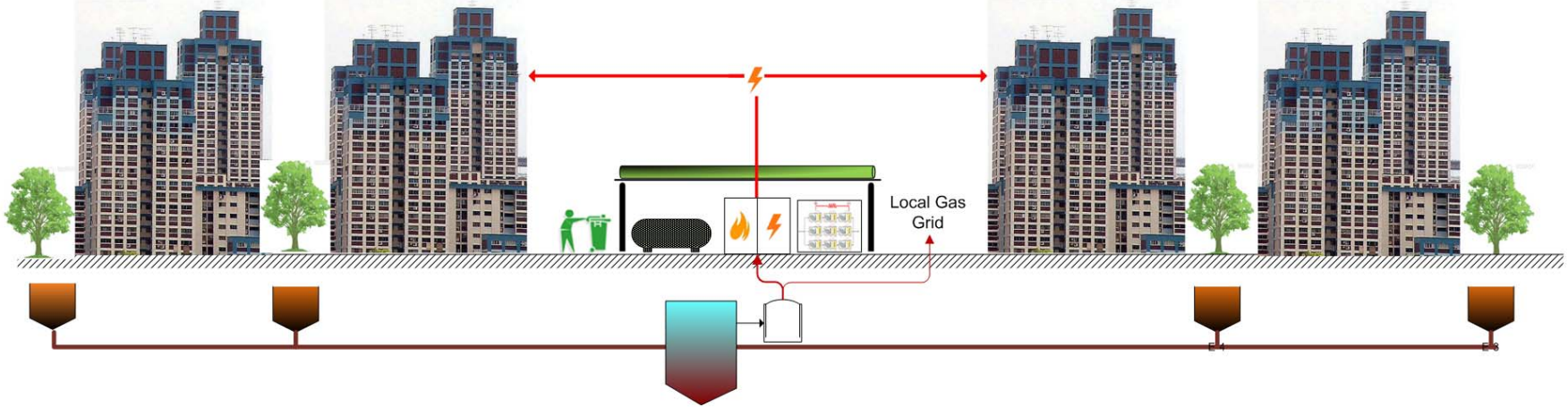
Waste is not waste

- Waste is a misplaced resource
- Waste residues can be converted into reusable/new materials, energy, and other products with value
- Natural resources are limited and depleted
- Waste can be potential sources for **resource recovery**

Issues of Current Waste Management

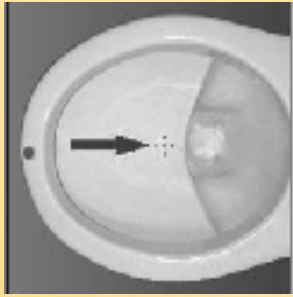
- We have not used resources efficiently
- The centralized waste management approach is energy-consuming; it was ok but not for the future
- Liquid waste: activated sludge process (water flushing + aeration + nitrification and de-nitrification + sludge dewatering + ...)
- Solid waste: collection and transportation (energy consuming) + emissions from incineration and landfilling (land contamination)

CRP Project: Communities as Renewable Resource Recovery Centers

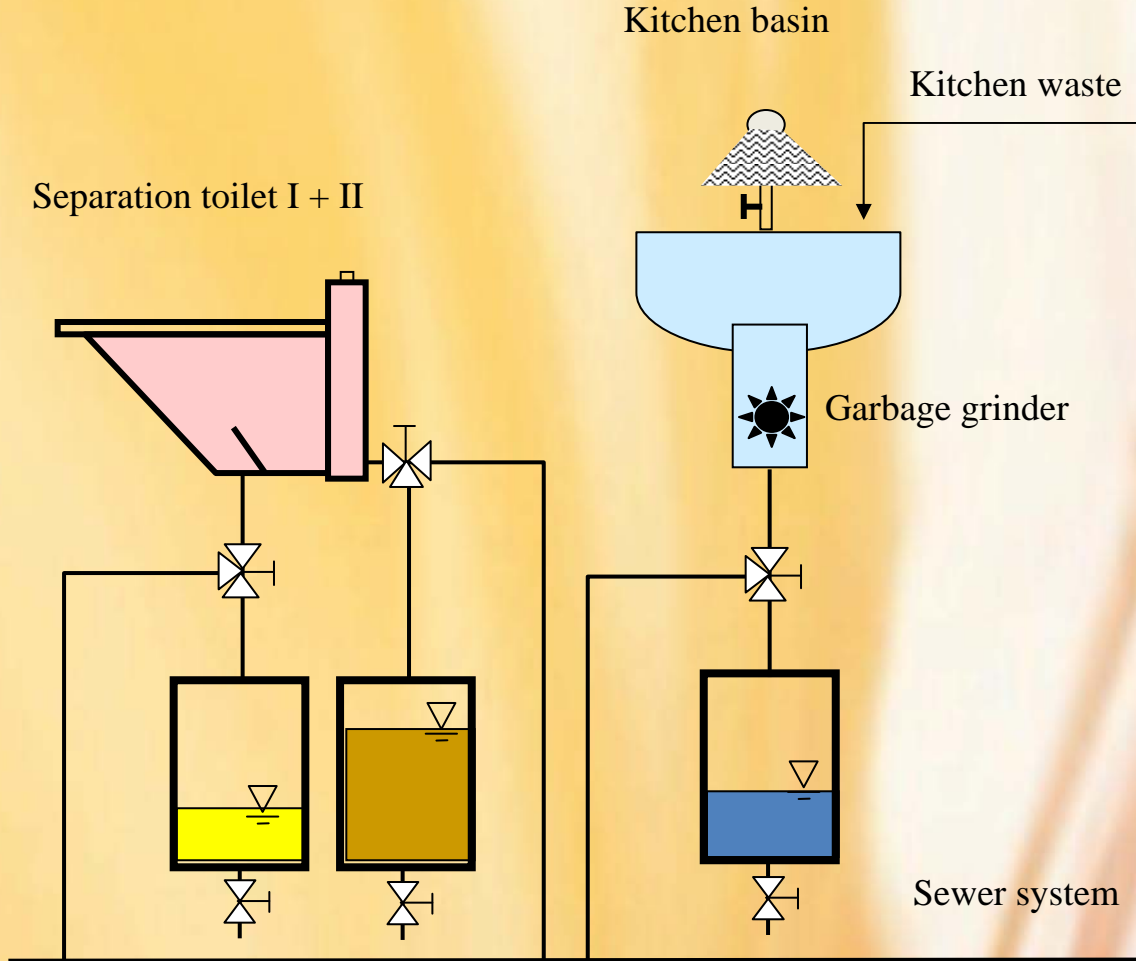




Separation of Brown Water, Yellow Water, and Kitchen Waste



Separation toilet I + II



Separation toilet + Storage tank

Storage tank Yellow water

Storage tank Brown water

Storage tank Kitchen waste

Sewer system

Kitchen basin

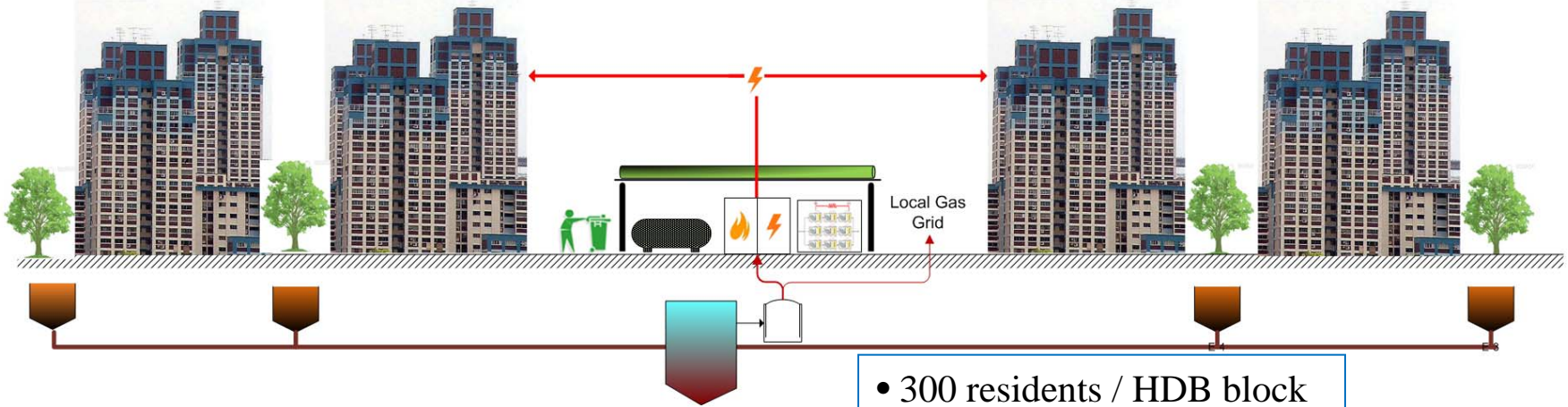
Kitchen waste

Garbage grinder

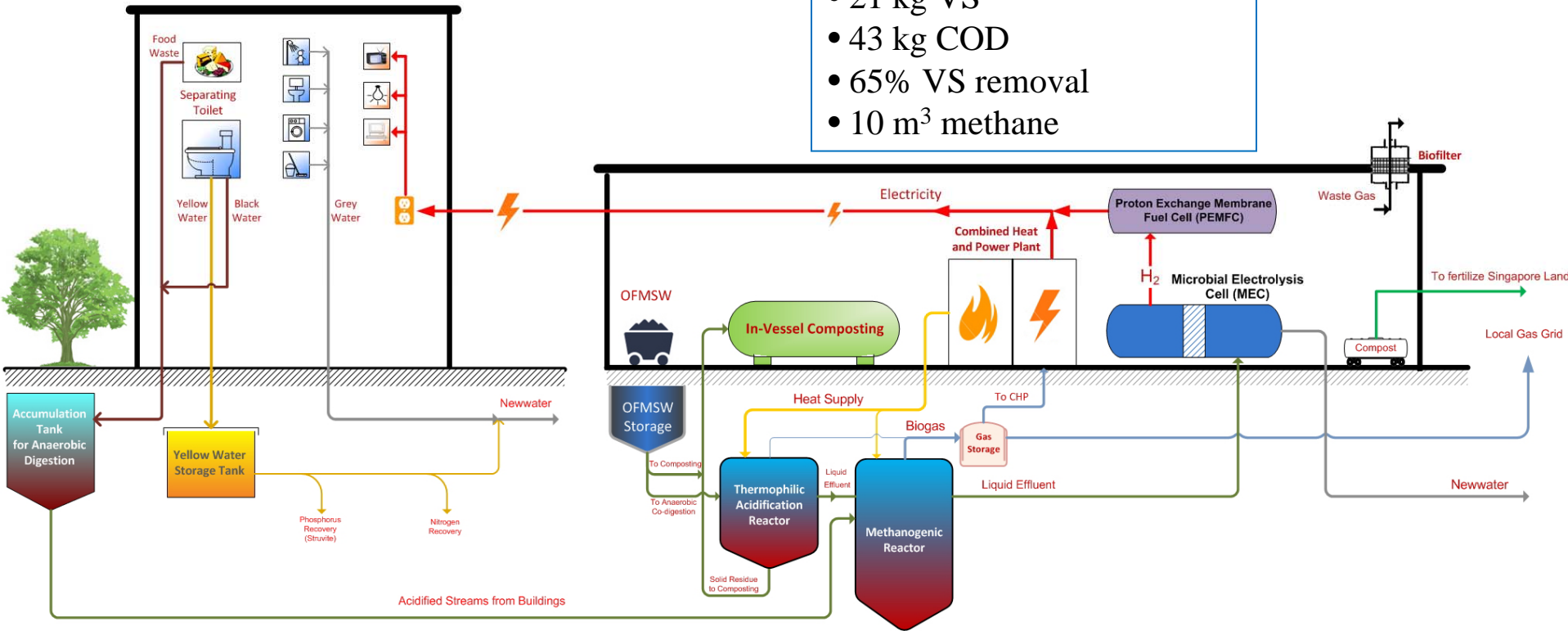


Wash basin + Garbage grinder

CRP Project: Communities as Renewable Resource Recovery Centers

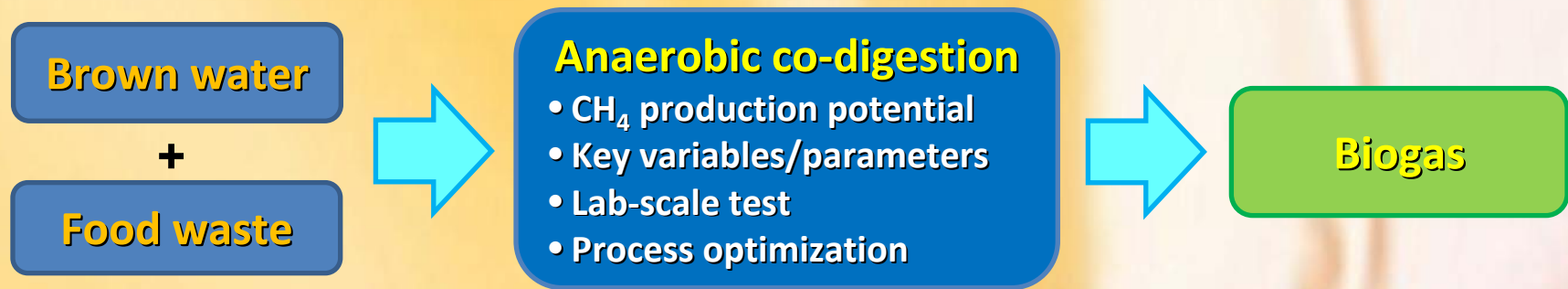


- 300 residents / HDB block
- 21 kg VS
- 43 kg COD
- 65% VS removal
- 10 m³ methane

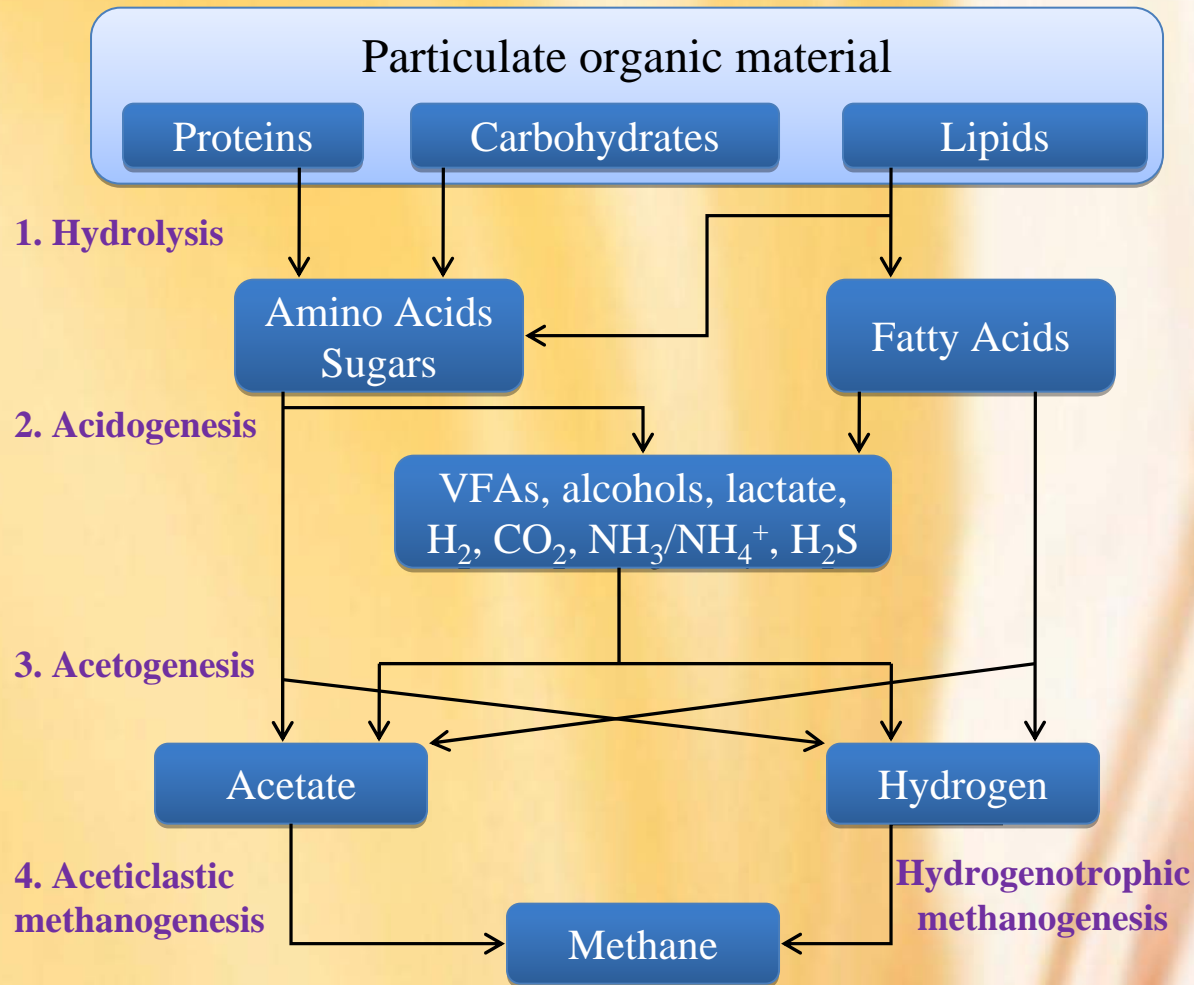


Research Objectives and Scopes

- ❑ To develop a three-phase AD system to optimize the production of methane from the co-digestion of Food Waste and Brown Water
- ❑ Partial-aerobic hydrolysis reactor, an anaerobic acetogenic UASB reactor and a methanogenic UASB reactor



Four Steps in Anaerobic Digestion



Adapted from Gujer and Zehnder (1983)

Batch Study on Anaerobic Co-digestion of Brown Water and Food Waste

Experimental Design

	Substrate(s)	Organic Loading (g VS/L)	F/I ratio
1	Brown Water	0.3, 0.5, 1.0, 2.5	0.12, 0.20, 0.40, 1.0
2	Food Waste	0.3, 0.5, 1.0, 2.5	0.12, 0.20, 0.40, 1.0
3	Brown Water + Food Waste	1.0, 1.0, 1.0, 2.0	0.40, 0.40, 0.40, 0.80

Seed Sludge = 20% (v/v)

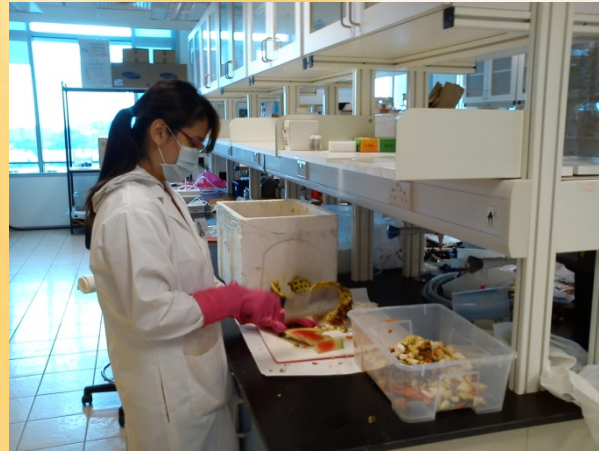
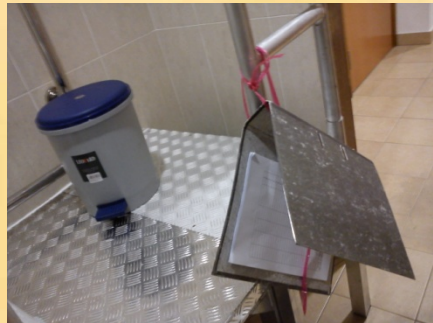
Working Volume = 70mL

BW:FW mixing ratio (in terms of VS added) = 1:1, 3:7, 7:3, 1:1

Materials and Methodologies

1. Collection and treatment of samples
2. Sample Preparation
3. Measuring gas production
4. Analytical Methods

1

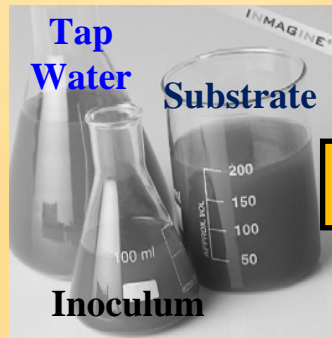


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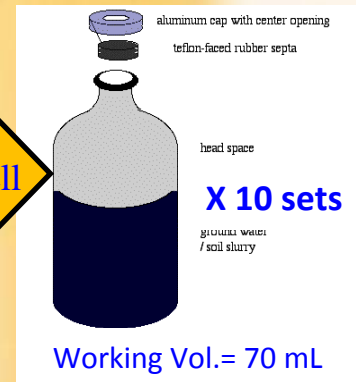
2



Prepare 1 L mixture



Mix Well



Conditions:

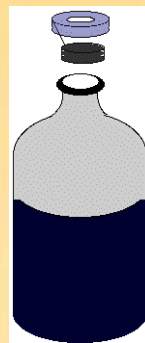
- Batch –30 days
- Anaerobic
- 35°C
- Continuous mixing

3



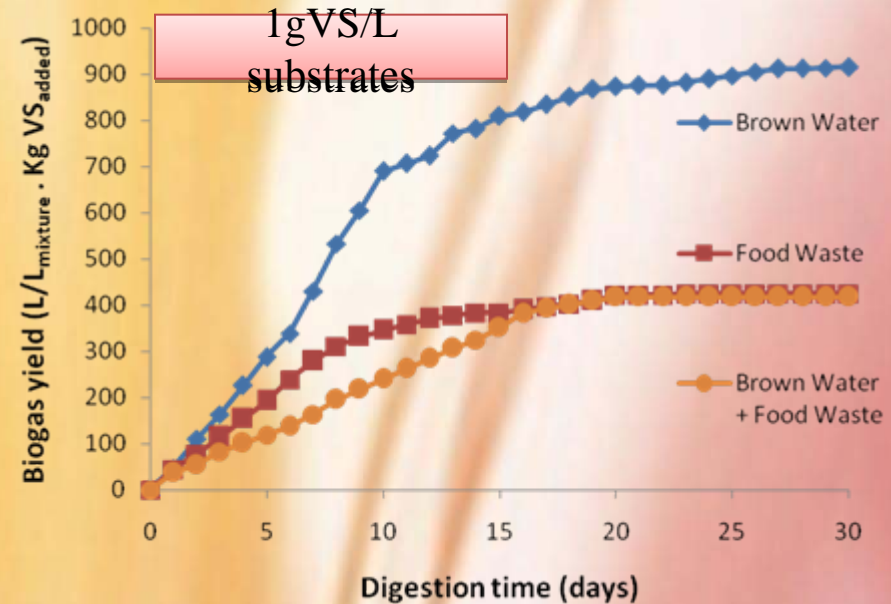
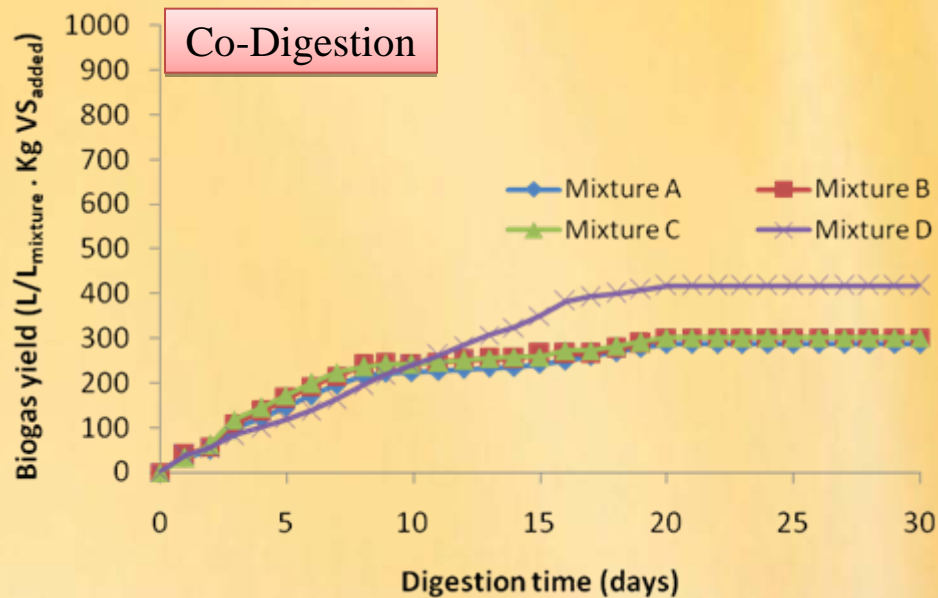
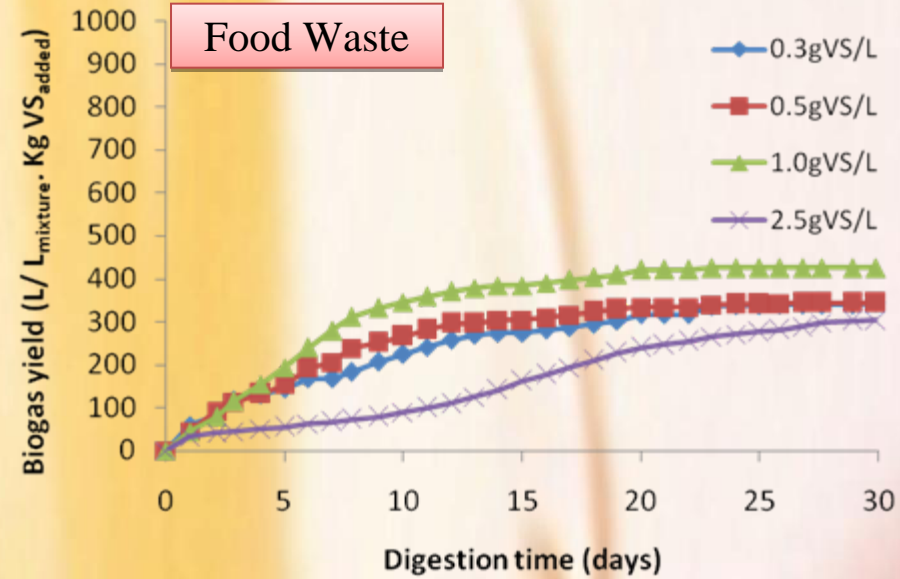
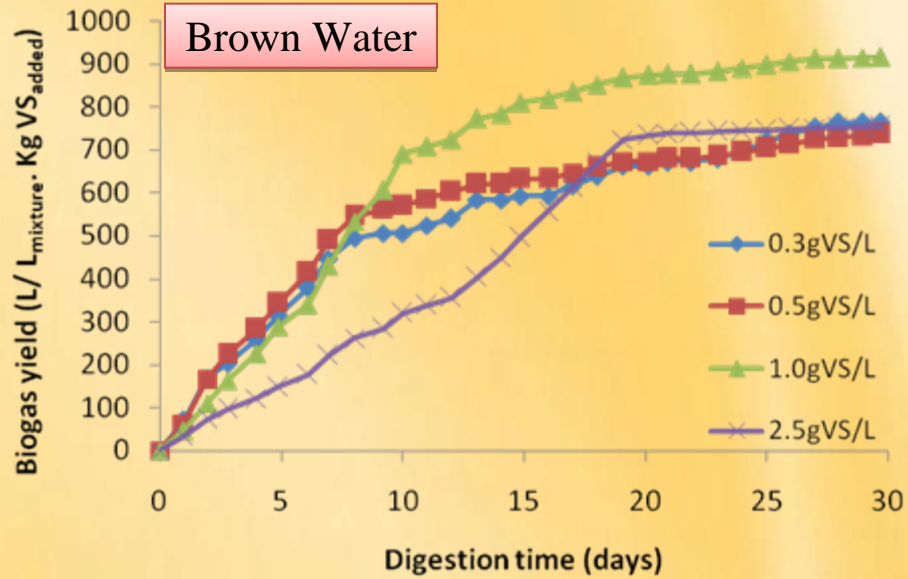
Intermittent pressure release method

4



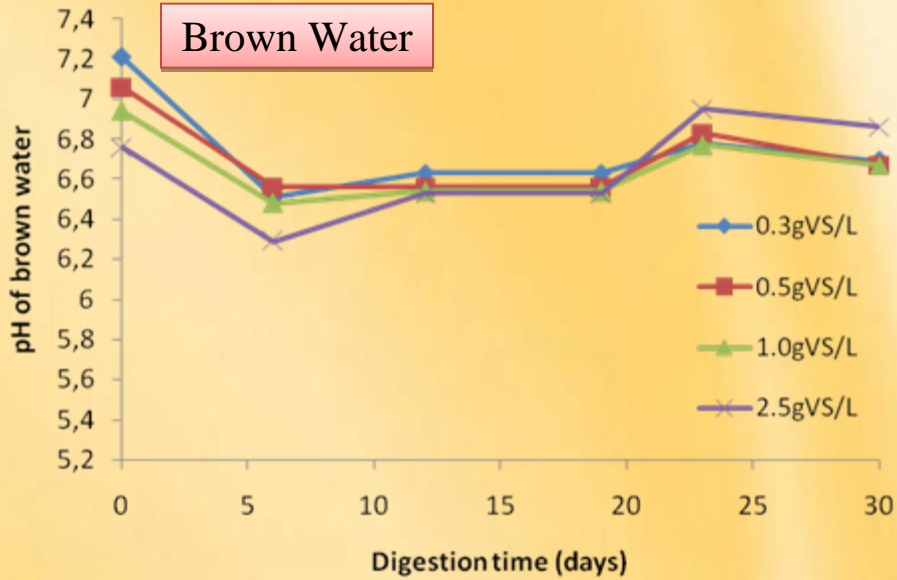
- Analytical Tests (every 7 days/ at the end of study)
 - pH
 - TS, VS
 - Biogas Composition – %CO₂, %CH₄
 - COD
 - VFA

Results (Biogas Yield)

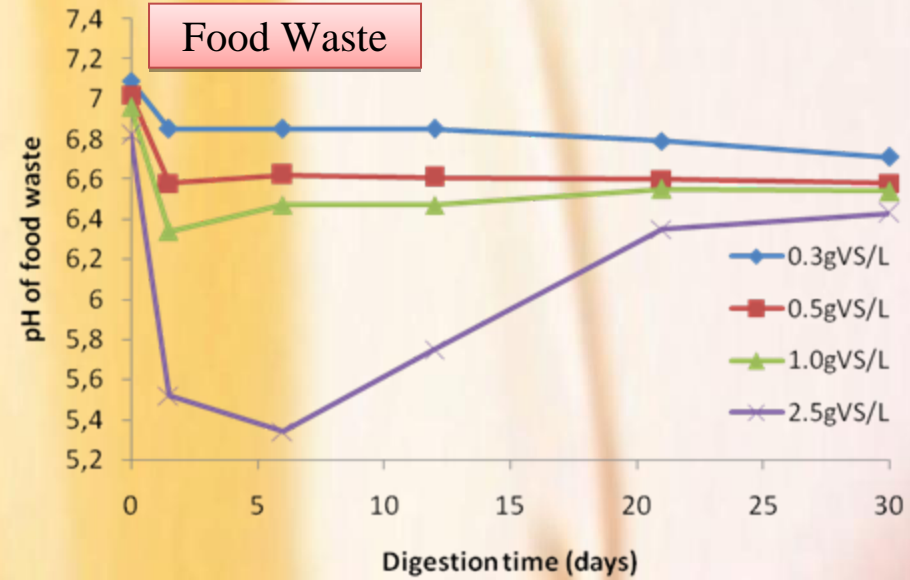


Results (pH)

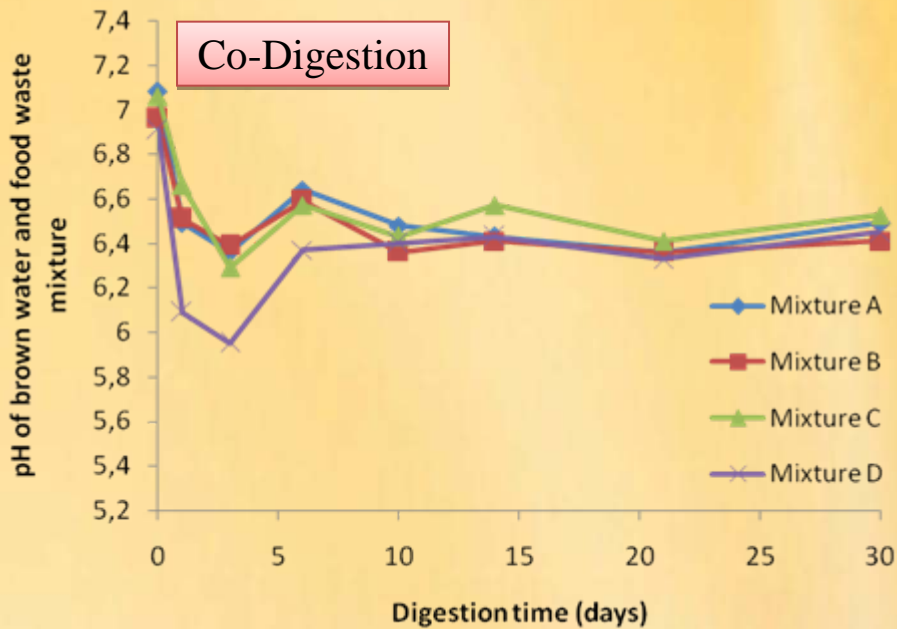
Brown Water



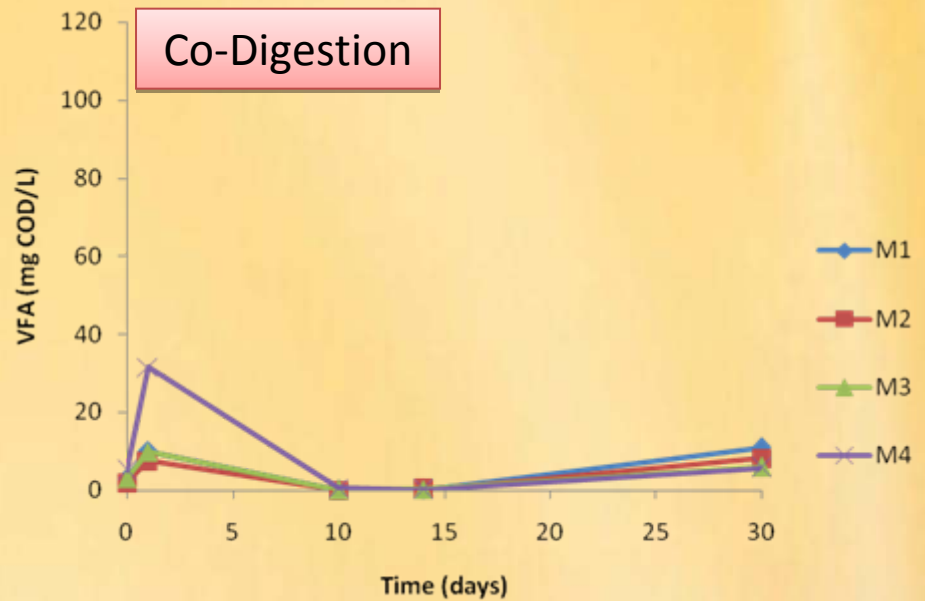
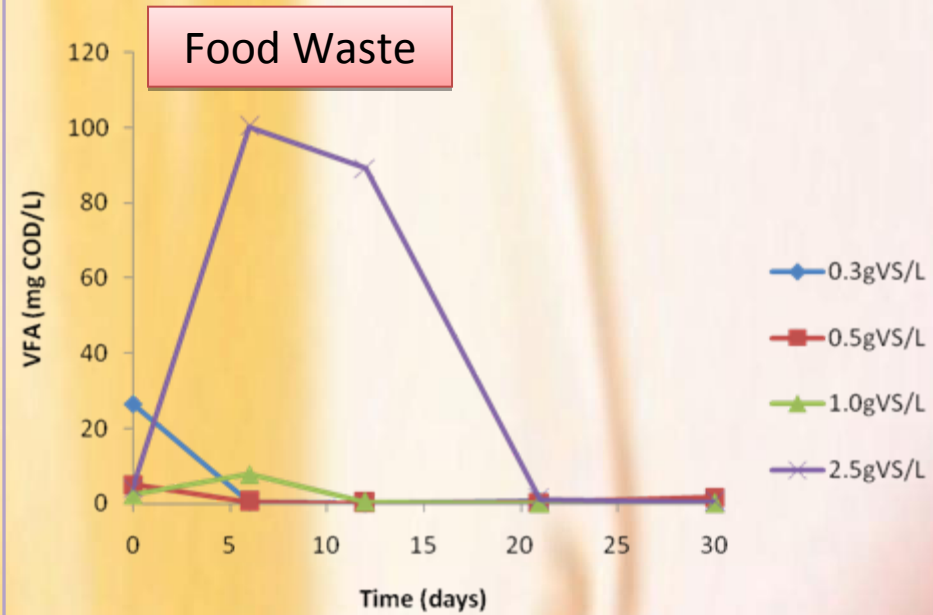
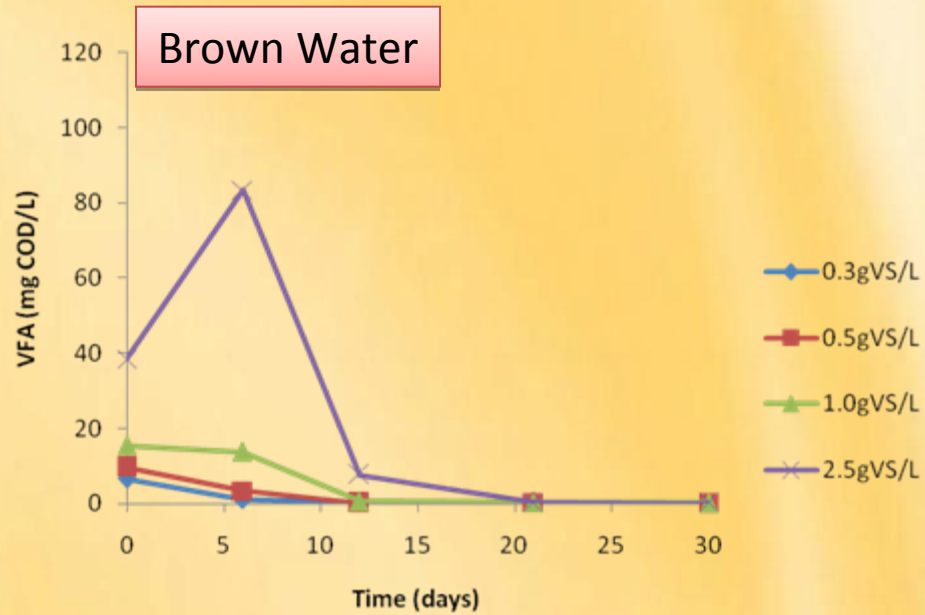
Food Waste



Co-Digestion

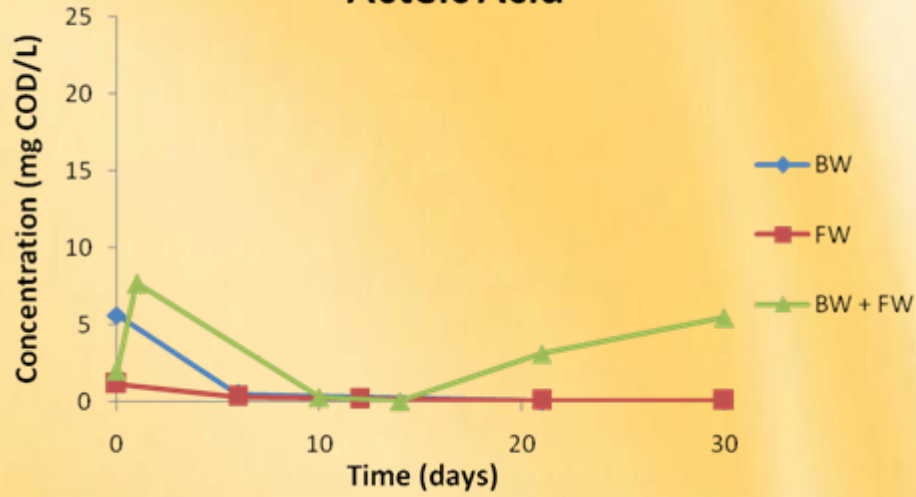


Results (Total VFA)

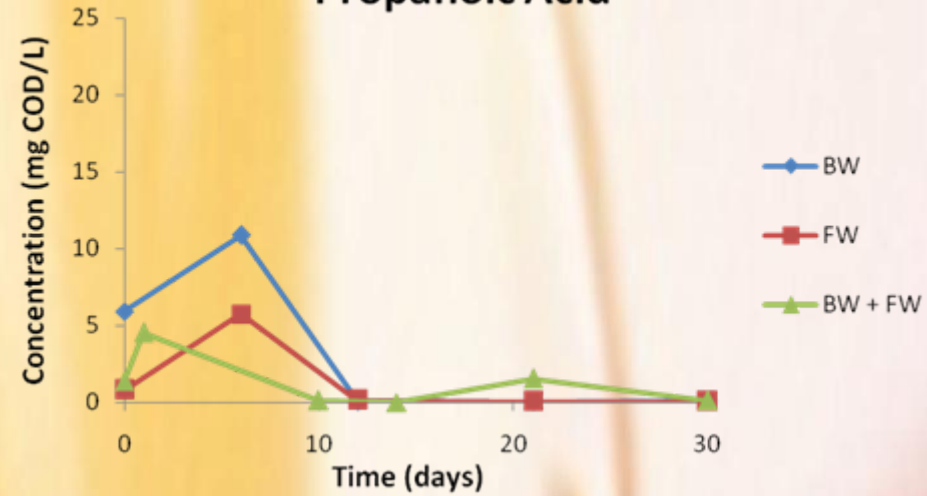


Results (Individual VFA)

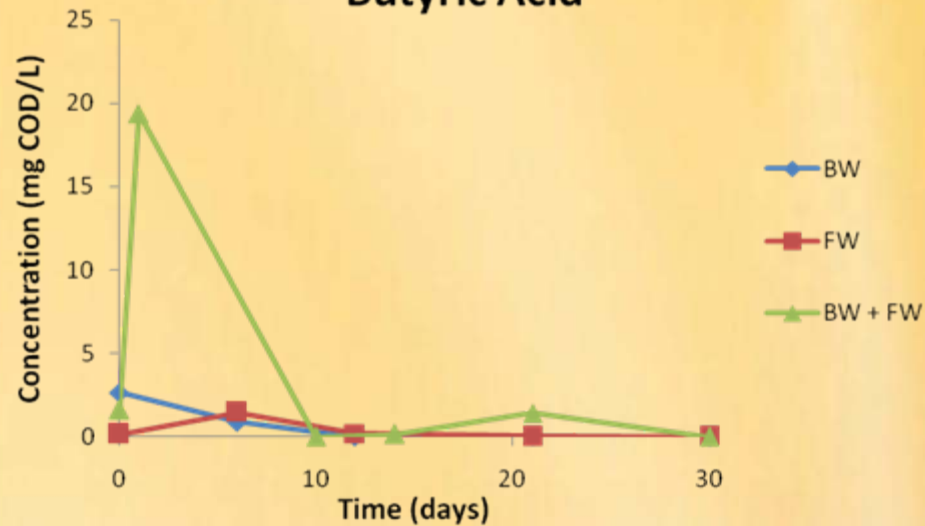
Acetic Acid



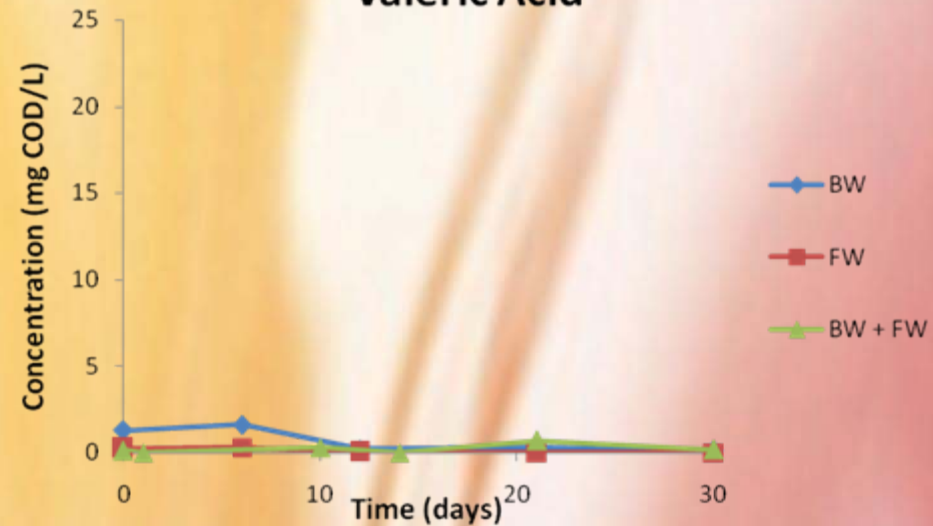
Propanoic Acid



Butyric Acid



Valeric Acid



Conclusions on Batch Study

❑ **Brown water / Food waste Tests**

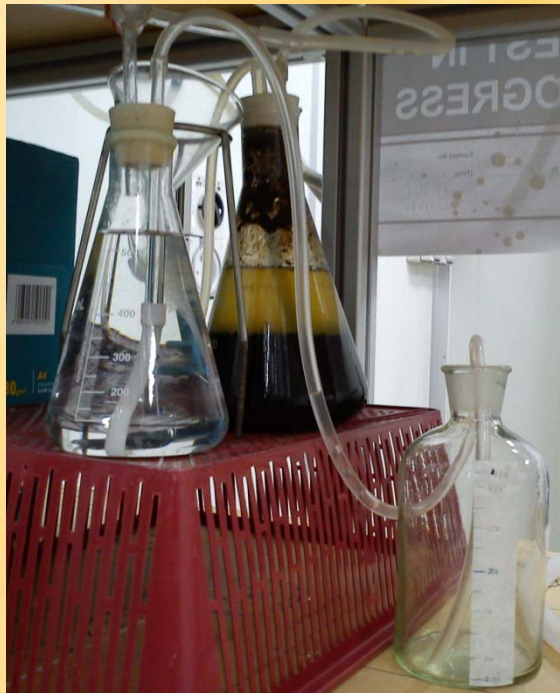
- At least 90% of final biogas yield & VS reductions achieved in 21 days
- Methane content: 55 – 78%
- Biogas production potential of BW > FW
- F/I of 0.4 – 1.0

❑ **Co-Digestion Tests**

- Varying mixing ratio has little effect on biogas yields
- Acetic acid accumulation towards the end of digestion period
- Requires longer degradation time

Future Work

- ❑ Synergistic relationship between BW & FW in co-digestion
- ❑ Continuous system
- ❑ Phase separation
 - Reduce HRT in each phase
 - Minimize VFA accumulation effects



Single-phase Fed-batch



Two-phase Continuous

Acknowledgements

- Gujer, W., Zehnder, A.J.B. 1983. Conversion processes in anaerobic digestion. *Wat Sci Tech* 15(8-9), 127-167
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