Comparing different strategies for start-up of thermophilic anaerobic digestion: Reactor stability and microbial community structure

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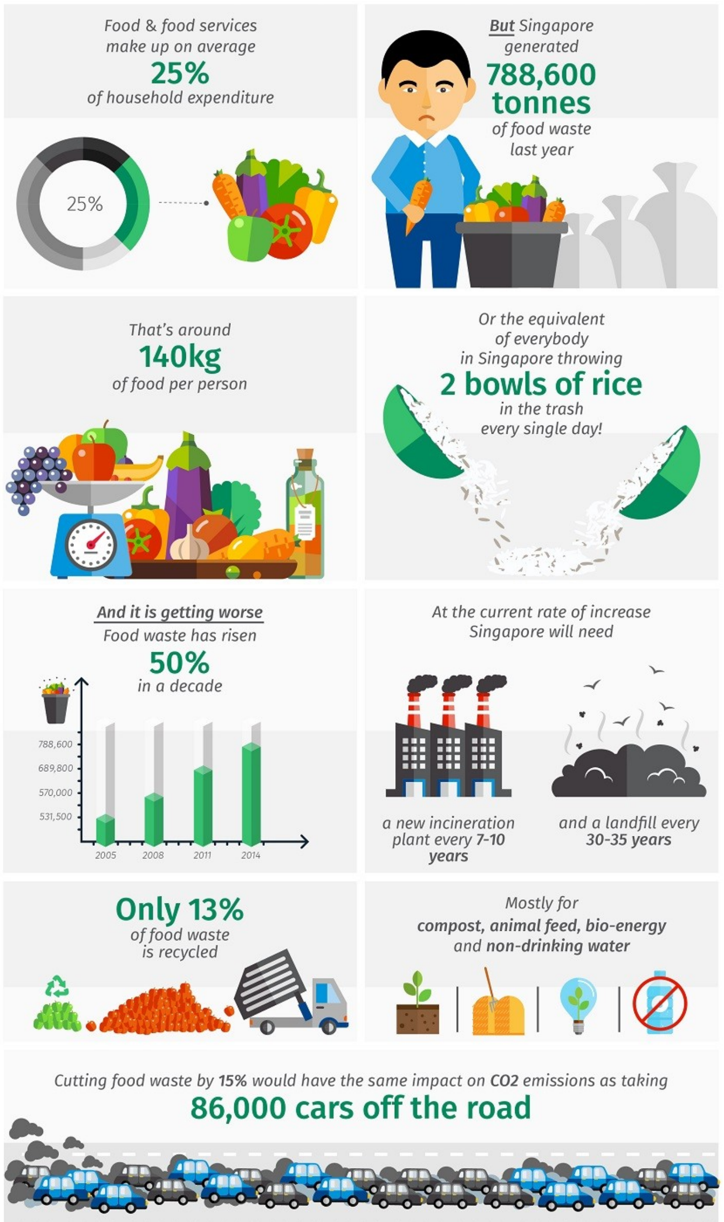
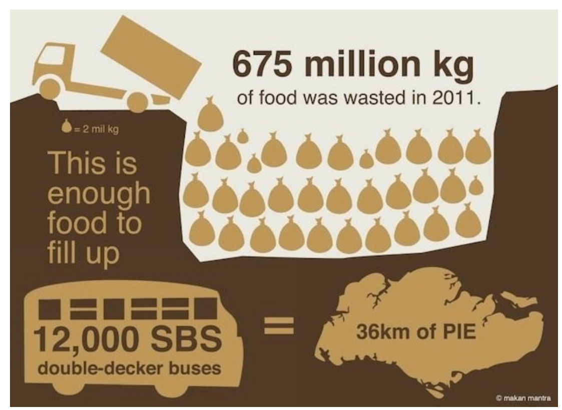
INTRODUCTION

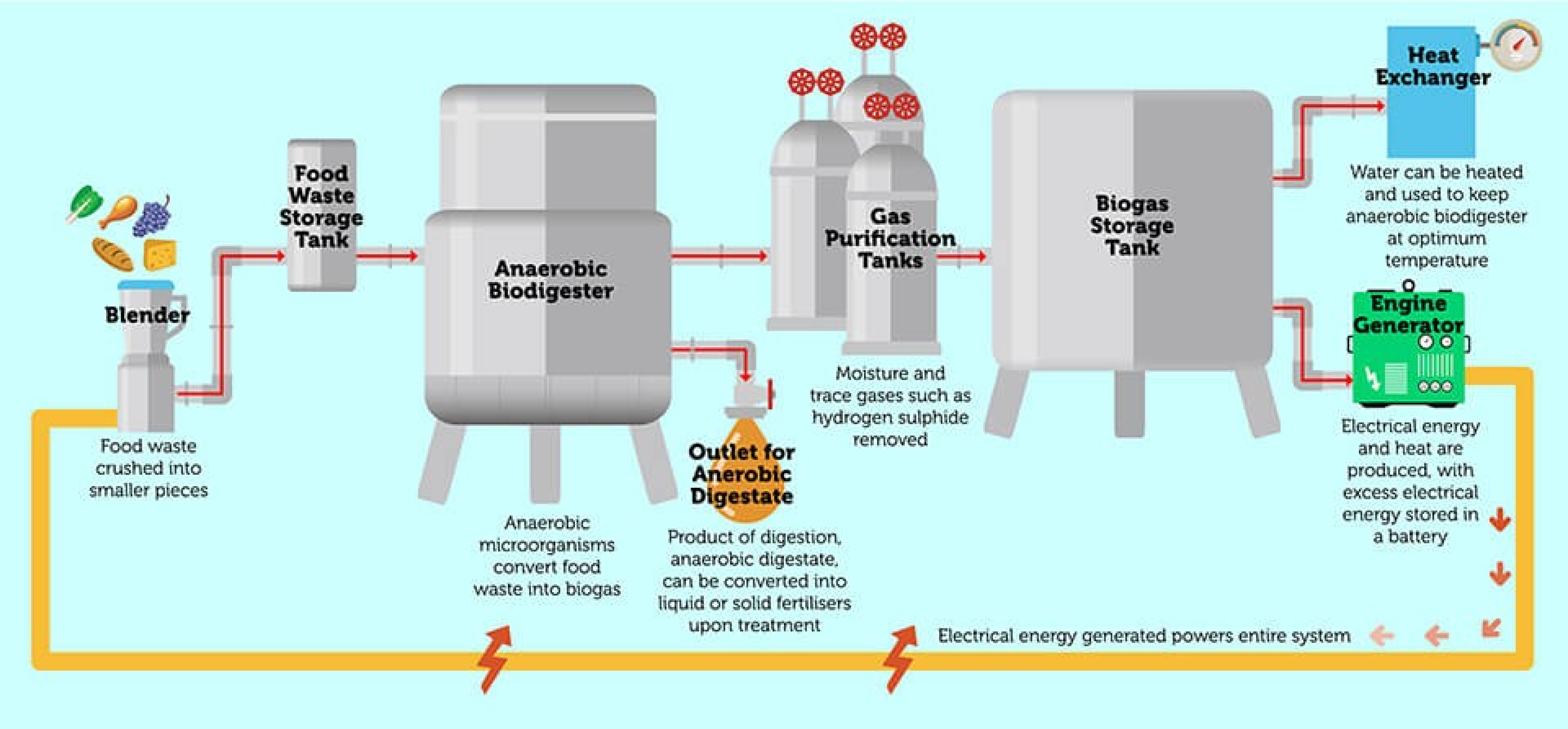


- Globally, ~1.3 billion tonnes/year wasted
- One third of food produced for human consumption
- Singapore: 809,800 tonnes/year generated
- Mostly incinerated



Figures of 2015's food waste. Image: Zero Waste SG

SELF-SUSTAINING ANAEROBIC DIGESTION SYSTEM FOR FOOD WASTE



- Waste volume reduction: 80-90%
- Reduce GHG emission
- Nutrient recycling
- Energy recovery

PILOT DEMONSTRATION

40 kg/day food waste
Digester working volume: 800L

5 m³ biogas

60% CH_4 content

0.4 L-CH_4/g-VS

43.2 kWh electricity generated

4-8 kWh electricity consumed

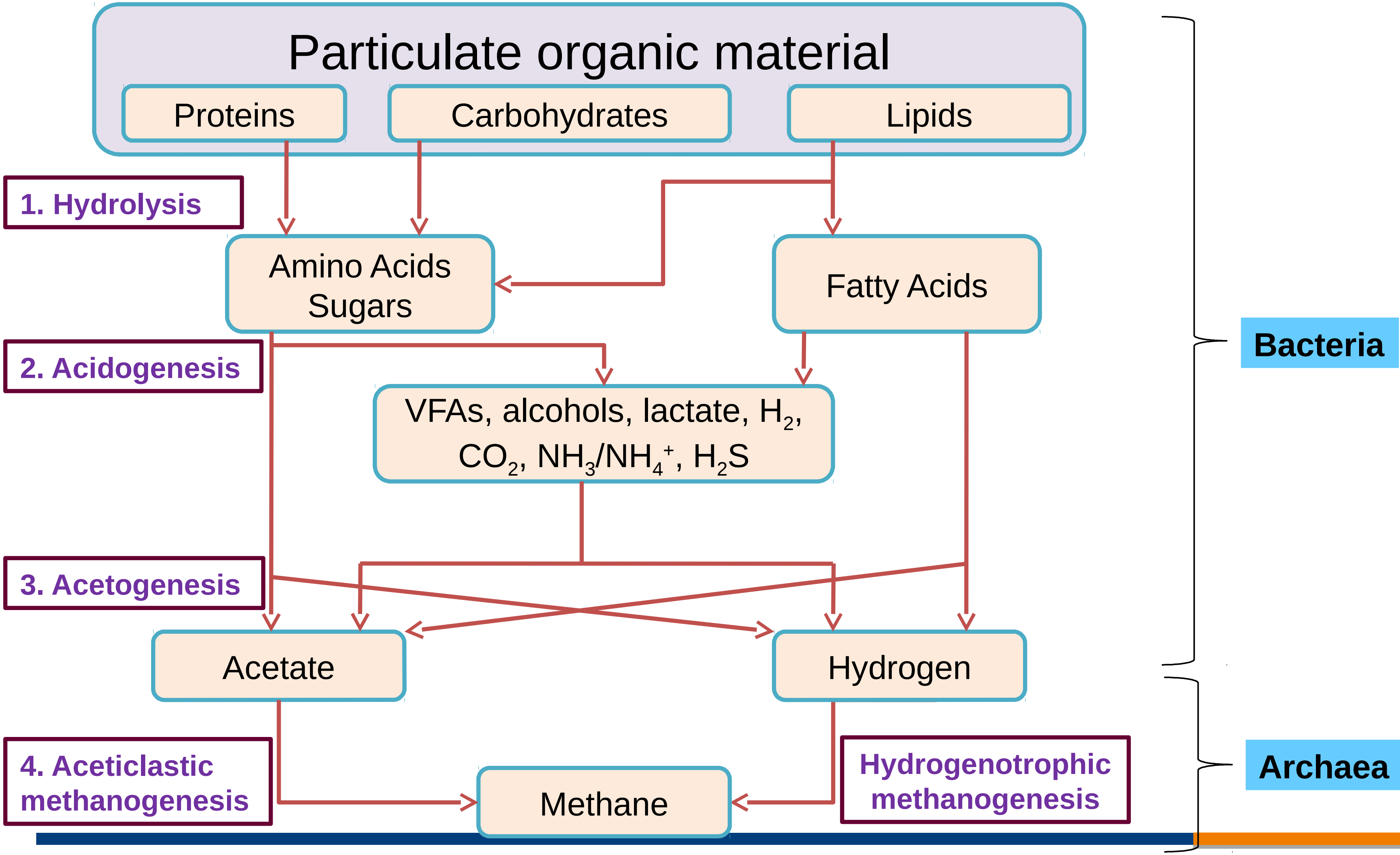
40 kg/day fertiliser

Anaerobic Digestion System

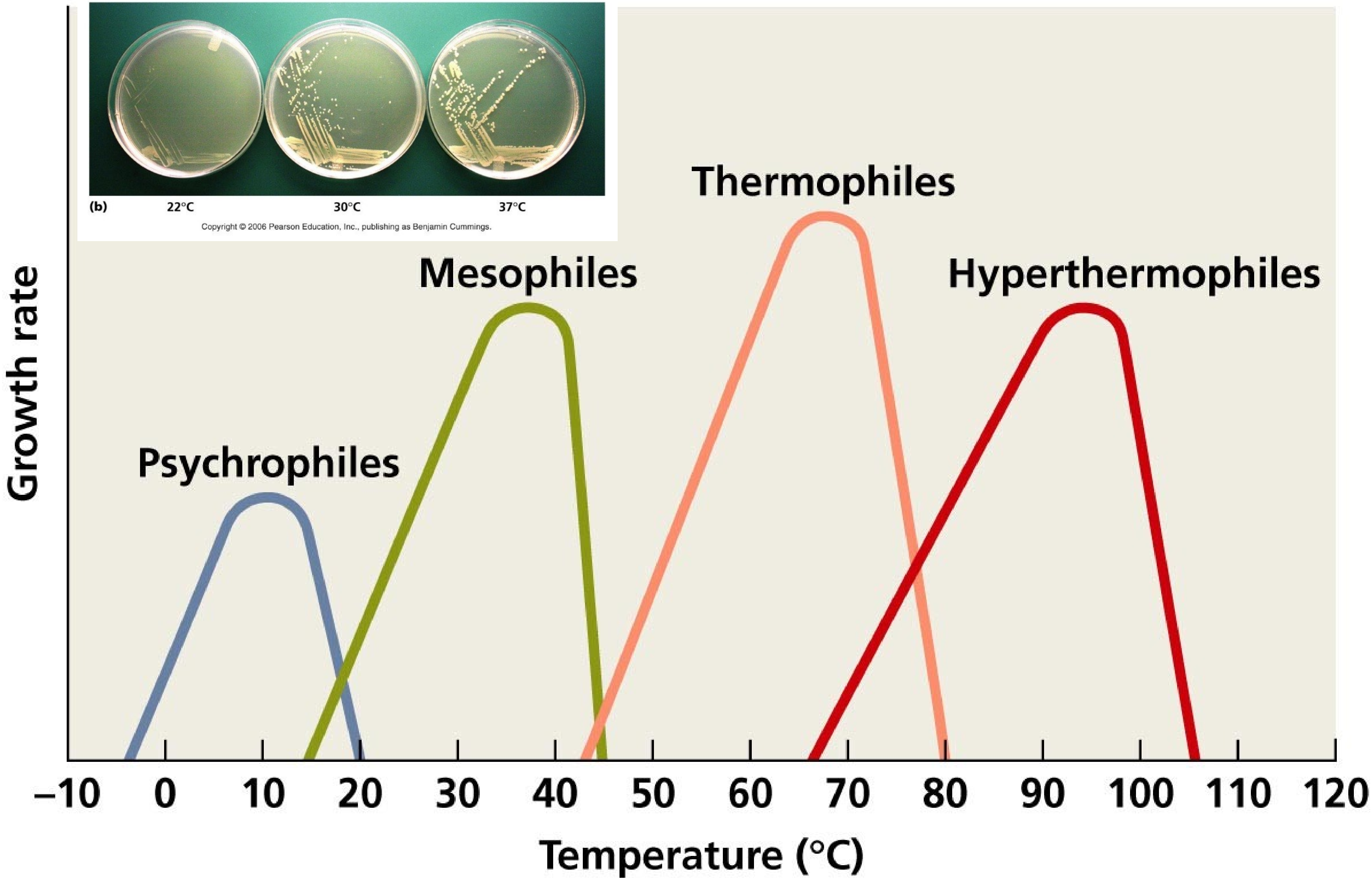
Phone Charging System

Crops fertilized by digestate

ANAEROBIC DIGESTION IS A BIO-CHEMICAL PROCESS



Adapted from Gujer and Zehnder (1983)


(b)
22°C
30°C
37°C
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Thermophiles
Mesophiles
Hyperthermophiles
Psychrophiles
Growth rate
–10
0
10
20
30
40
50
60
70
80
90
100
110
120
Temperature (°C)

THERMOPHILIC ANAEROBIC DIGESTION

ADVANTAGES OF THERMOPHILIC AD

- Higher biogas production
- Higher removal of pathogen, antibiotic resistant genes
- Smaller footprint

Limitations of thermophilic AD

- Lack of bulk thermophilic inocula
- More difficult to attain stable operation
- More prone to perturbations and inhibition (from ammonia, lipids, etc.)

OBJECTIVE

- Compare the efficiency of two different methods of transforming mesophilic sludge to thermophilic: one-step and step-wise temperature increase
- To determine the method for better start-up of thermophilic AD from a mesophilic digester
- Stability of reactors and shifts in microbial community structures were investigated

METHODOLOGY

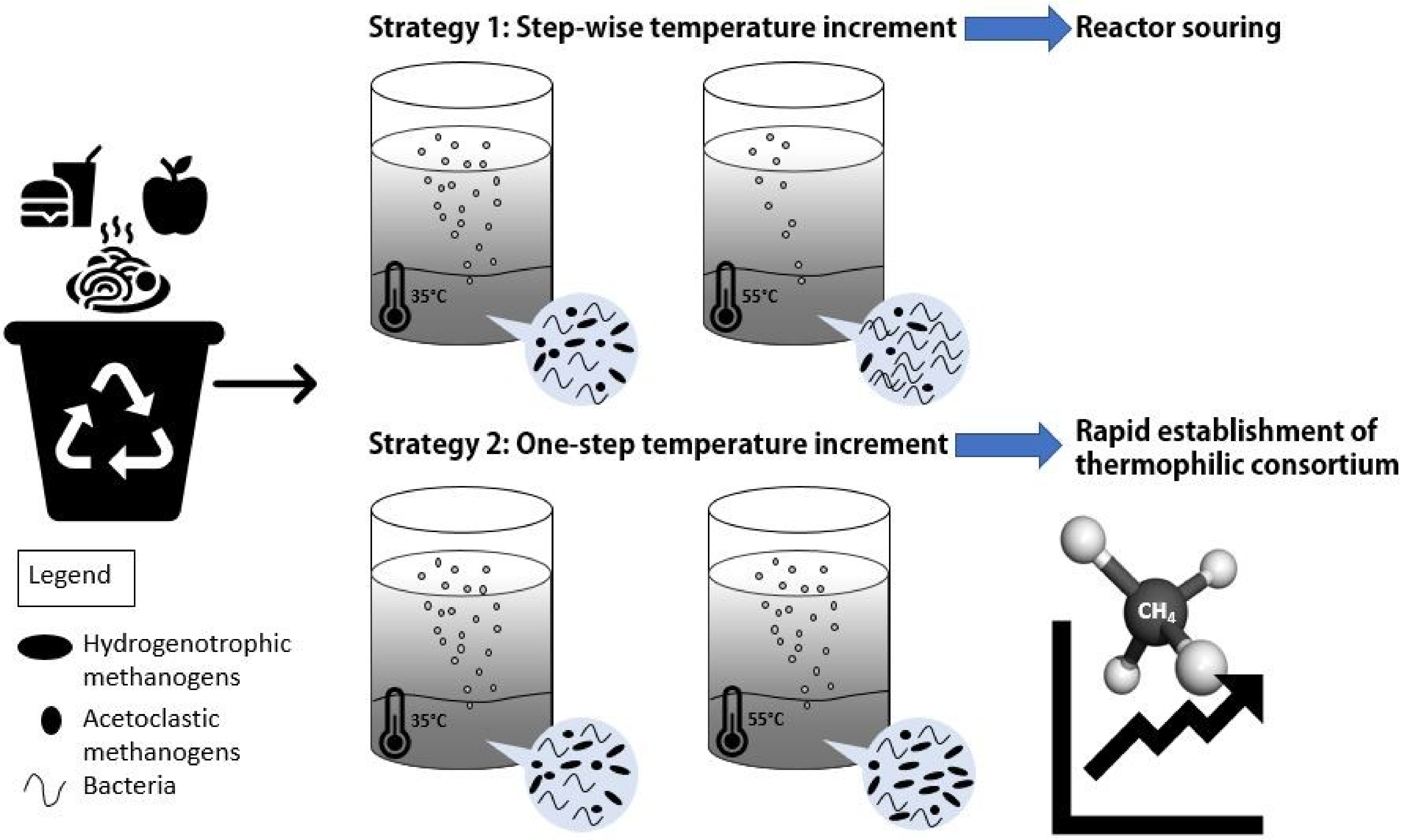
Food Waste

- UTown canteen
- 10 kg
- Mixture of mainly rice and noodles, smaller portions of meat and vegetables
- pH 4.3
- TS 33.2%, VS 22.5%
- C/N ratio 21

Start-up inoculum

- PUB sludge (pH 7.7, TS 15.5g/L, VS 11.2 g/L)
- FW sludge (pH 8.2, TS 21.5 g/L, VS 13.1 g/L)
- Mesophilic (35°C)

RESULTS


Strategy 1: Step-wise temperature increment
Reactor souring
35°C
55°C
Strategy 2: One-step temperature increment
Rapid establishment of thermophilic consortium
35°C
55°C
CH_4
Legend
Hydrogenotrophic methanogens
Acetoclastic methanogens
Bacteria

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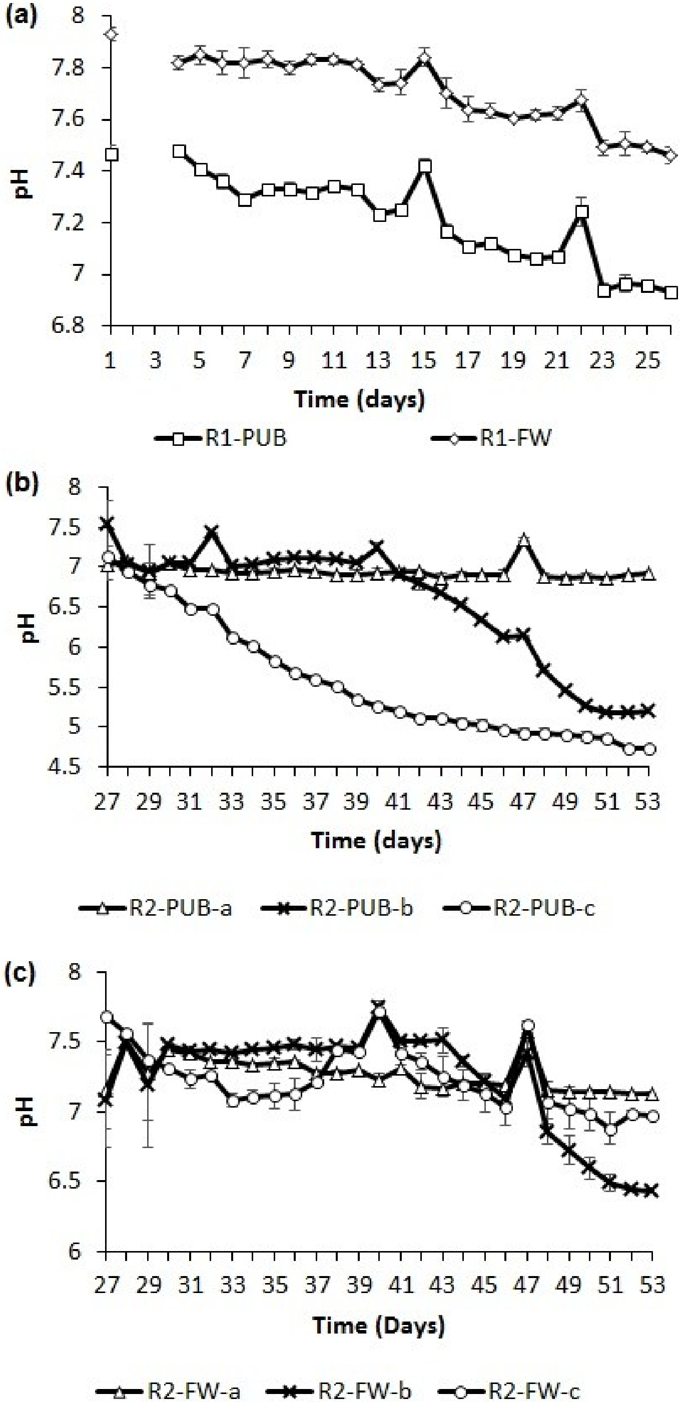
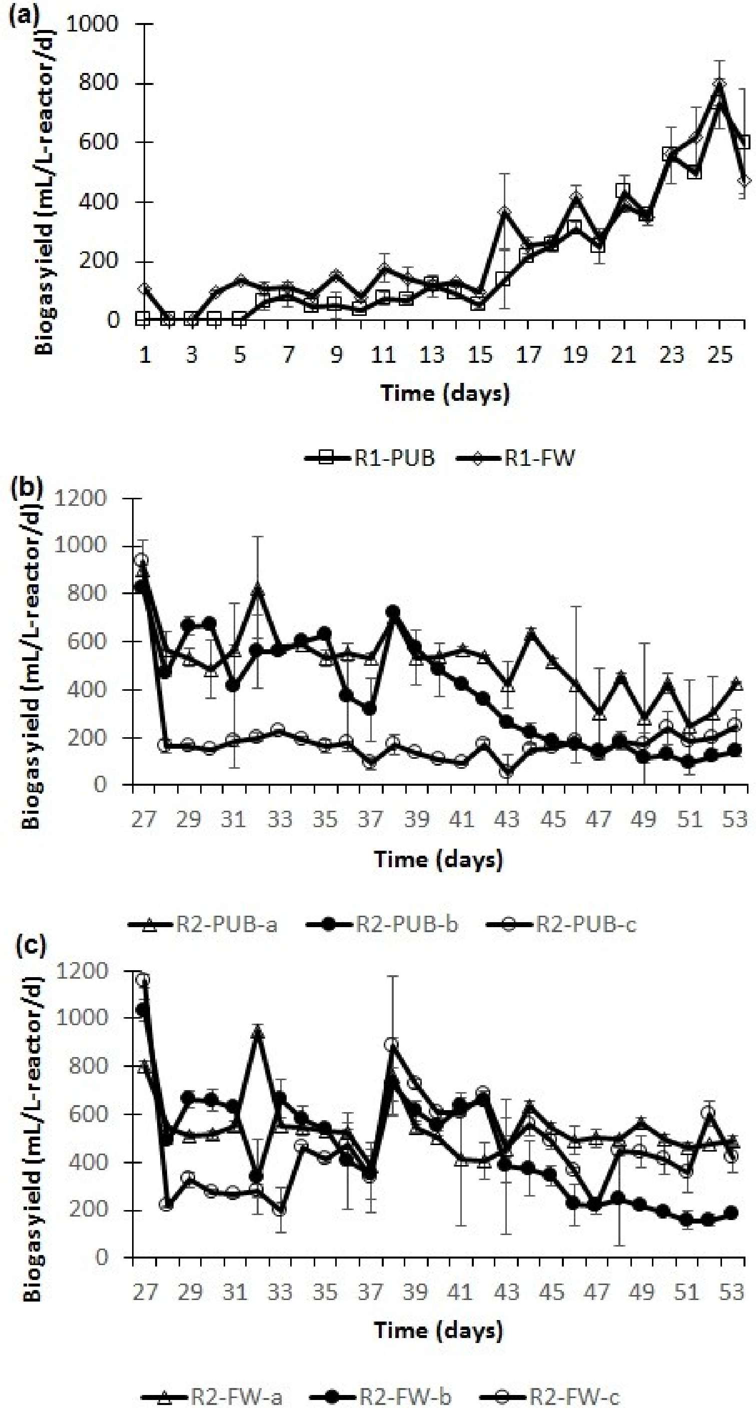
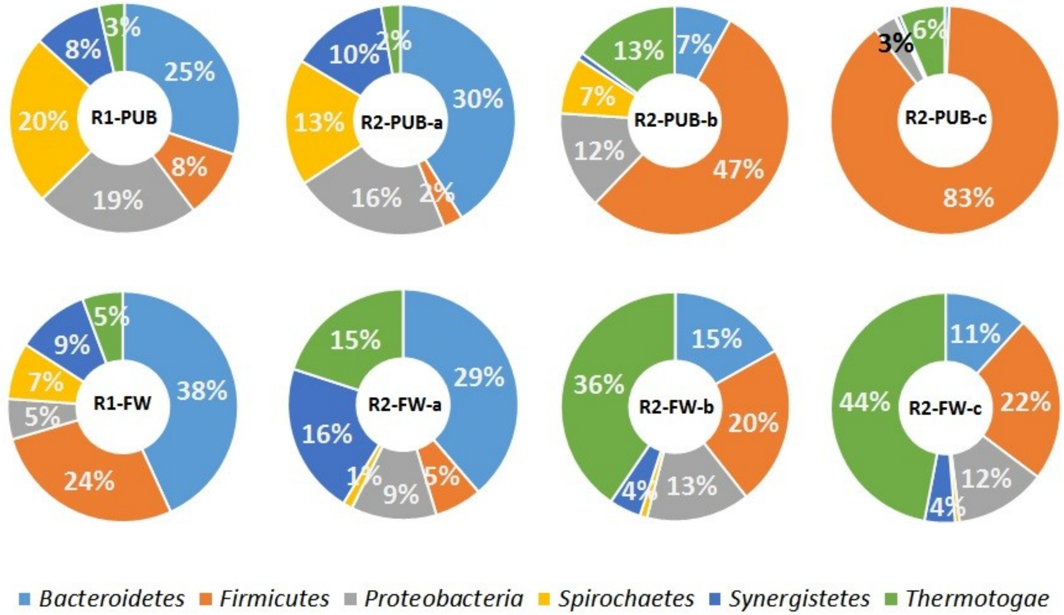
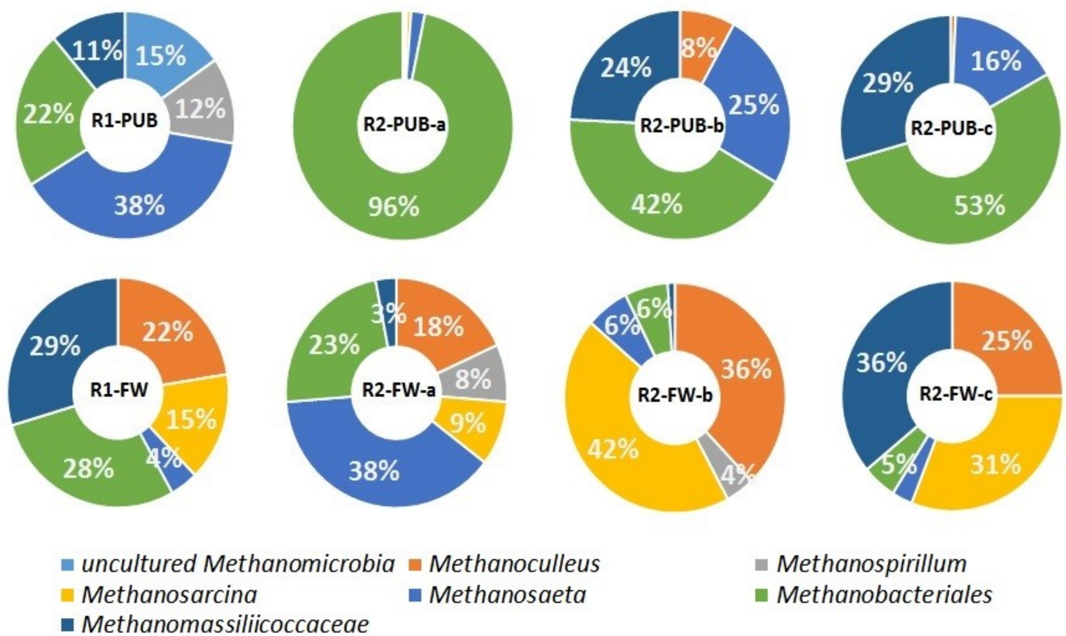




Res


R1-PUB
R2-PUB-a
R2-PUB-b
R2-PUB-c
R1-FW
R2-FW-a
R2-FW-b
R2-FW-c
Bacteroidetes
Firmicutes
Proteobacteria
Spirochaetes
Synergistetes
Thermotogae


R1-PUB
R2-PUB-a
R2-PUB-b
R2-PUB-c
R1-FW
R2-FW-a
R2-FW-b
R2-FW-c
uncultured Methanomicrobia
Methanoculleus
Methanospirillum
Methanosarcina
Methanosaeta
Methanobacteriales
Methanomassiliicoccaceae

COMPARISON TABLE

Step-wise temperature increase	One-step temperature increase
Biogas yield initially comparable to mesophilic control reactors	Biogas yield significantly lower than mesophilic control after temperature increased from 35°C to 55°C
Biogas yield < 200 mL/L/d when temperature exceeded 50°C	Biogas yield recovered to > 500 mL/L/d within 10 days
Great increase in absolute abundance of bacteria but reduced archaea	Higher microbial bio-diversity
Over-supply of AD intermediates unconsumed in time by methanogens, causing reactor souring	Predominance of thermophilic bacteria – *Thermotogae*, *Thermoanaerobacterales*, *Thermoanaerobacterium*, and *Methanosarcina*

CONCLUSION

- One-step temperature increase was the preferred start-up strategy for thermophilic AD
- Higher microbial bio-diversity and predominance of thermophilic bacteria played a major role in quick recovery from VFA accumulation and poor biogas yield
- Microbial consortia for thermophilic AD was established effectively by adopting the one-step temperature increase strategy


EXIT

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