# Optimization of Temperature-separated Two-stage Anaerobic Fermentation Process
# Treating waste activated sludge and food waste

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# Background information

WASTE ACTIVATED SLUDGE

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# Optimization of Temperature-separated Two-stage Anaerobic Fermentation Process

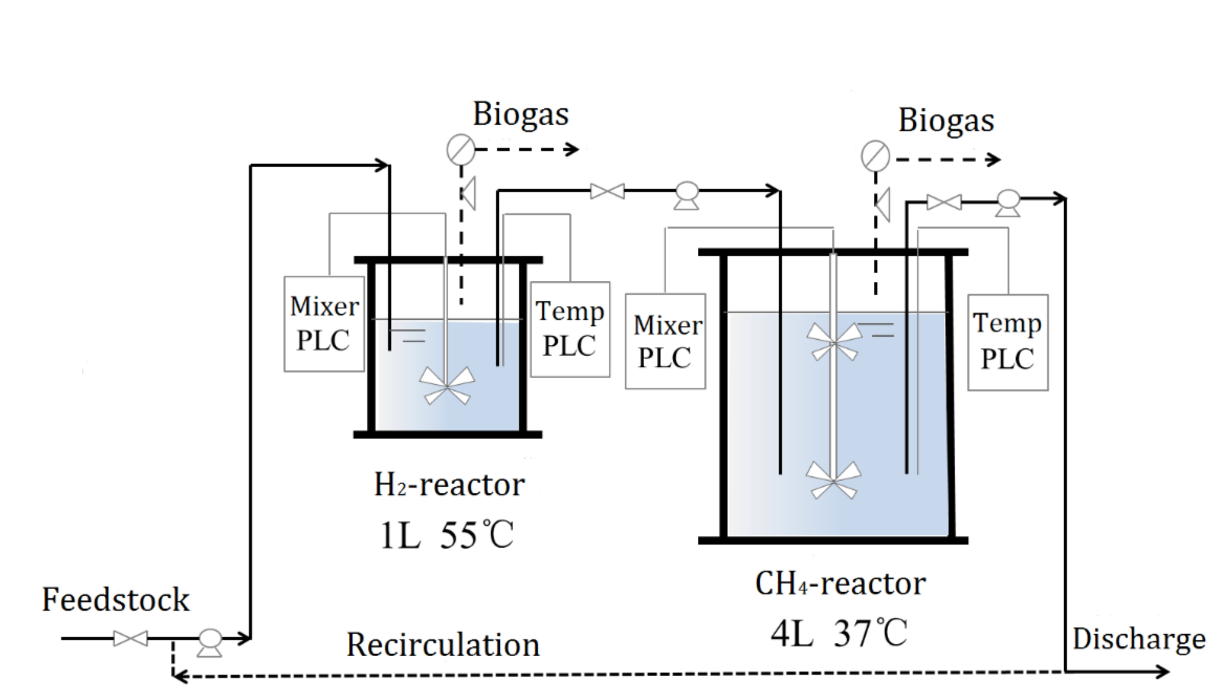



**Fig. 1** Schematic of the temperature-separated two-stage anaerobic process.

## M-SRT

Sludge retention time of methane producing stage

## SRR

sludge return ratios of the system

**Table 1** Operating conditions of different periods in the two-stage anaerobic fermentation process.

| Operating condition | $H_2$-reactor | | $CH_4$-reactor | | Operating time (d) |
|---|---|---|---|---|---|
| | SRT (d) | OLR (g-VS/L/d) | SRT (d) | OLR (g-VS/L/d) | |
| C-1 | 1 | 30.8 | 4 | 5.7 | 1-11 |
| C-2 | 1 | 30.3 | 8 | 2.9 | 12-32 |
| C-3 | 1.2 | 27.4 | 12 | 1.9 | 33-56 |
| SRR=1:1 | 1 | 30.6 | 4 | 5.5 | 1-16 |
| SRR=1:2 | 1 | 26.9 | 4 | 4.7 | 17-38 |
| SRR=2:1 | 1 | 34.3 | 4 | 6.4 | 39-58 |

## Results and discussion: Biogas production

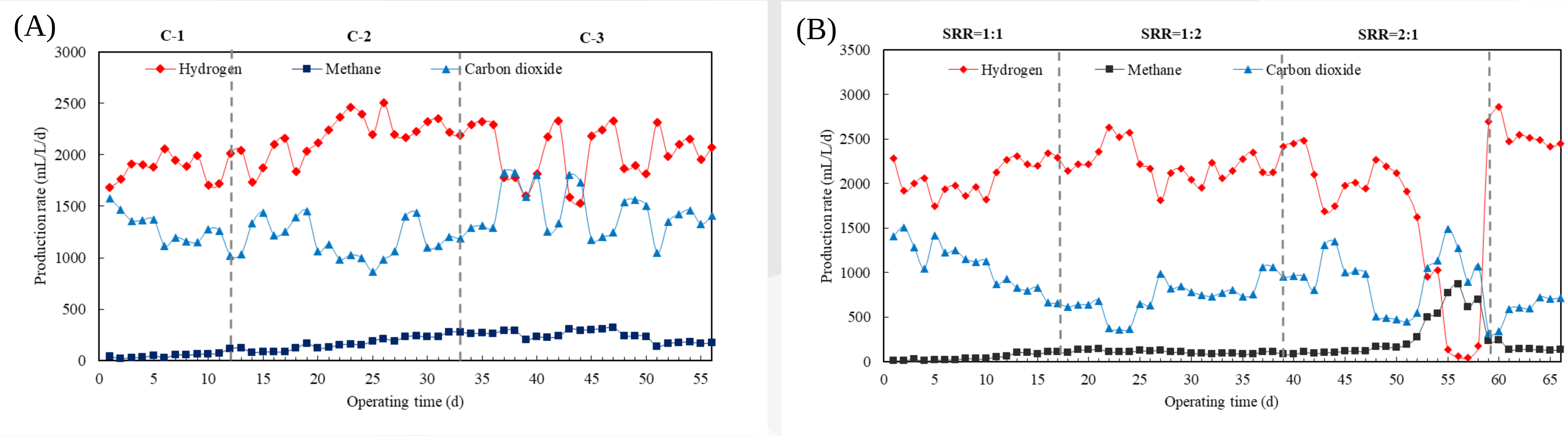



**Fig. 2** Production rate of $H_2$, $CO_2$ and $CH_4$ in $H_2$-reactor with different M-SRT (A) and SRR (B).

$H_2$ production in $H_2$-reactor could be promoted by properly prolonging M-SRT.

# Results and discussion: Biogas production

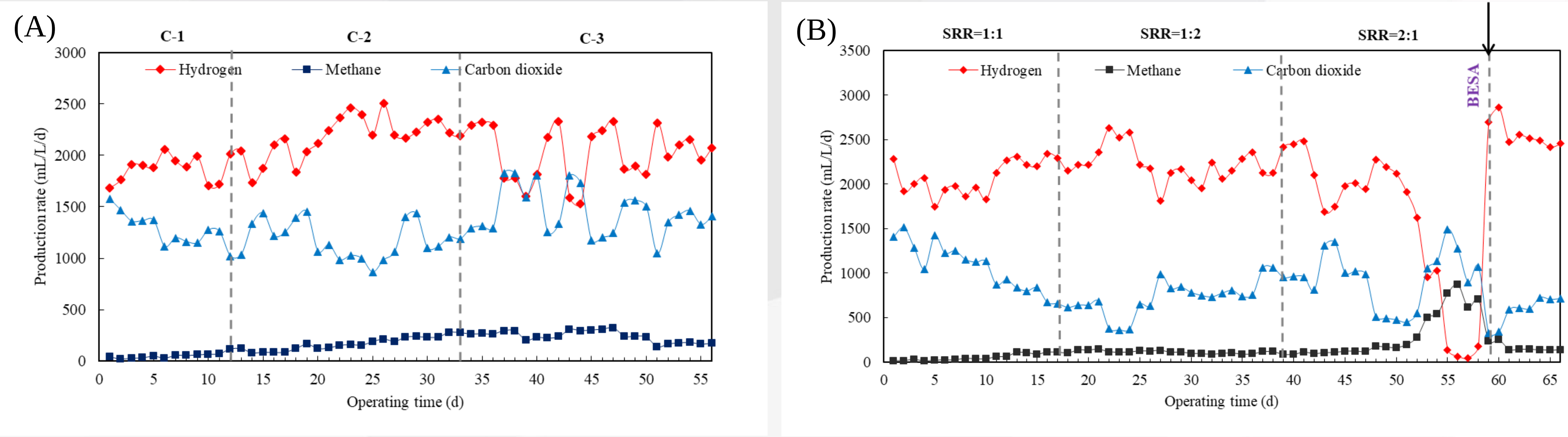


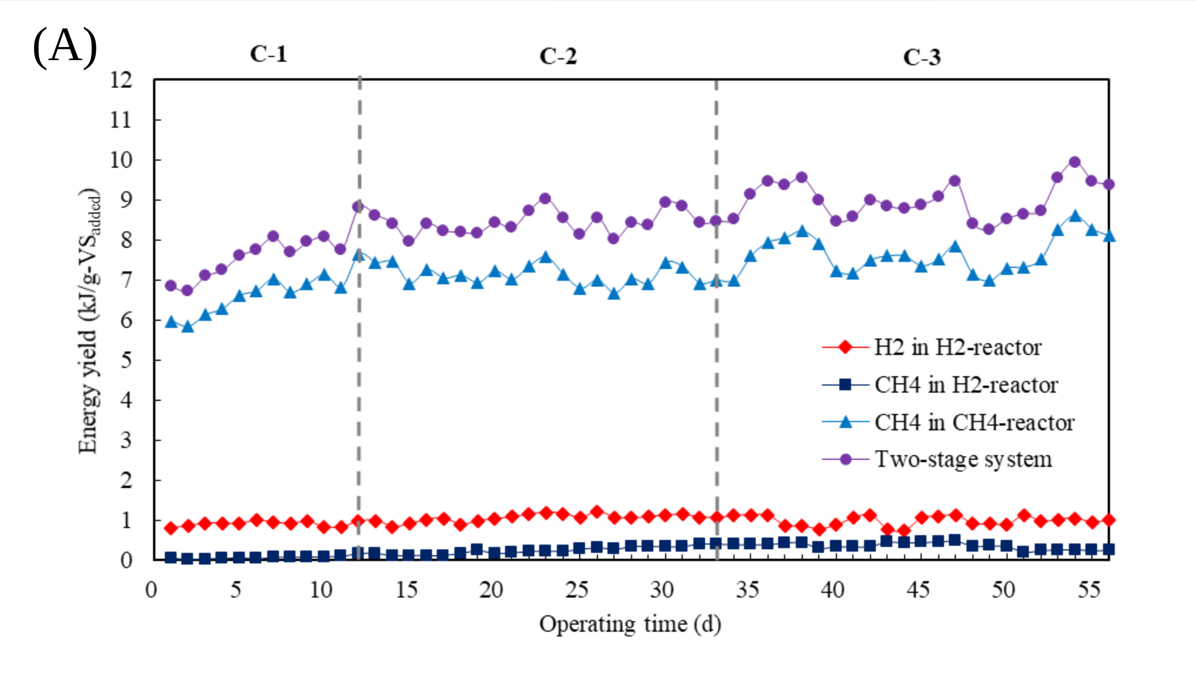

**Fig. 2** Production rate of $H_2$, $CO_2$ and $CH_4$ in $H_2$-reactor with different M-SRT (A) and SRR (B).

SRR=2:1 collapse of $H_2$ production

Added sodium 2-bromoethanesulphonate (BESA) recovery of $H_2$ production

The stage in $H_2$-reactor transferred from acidogenic stage to methanogenic stage with higher SRR.

# Results and discussion: Energy yield



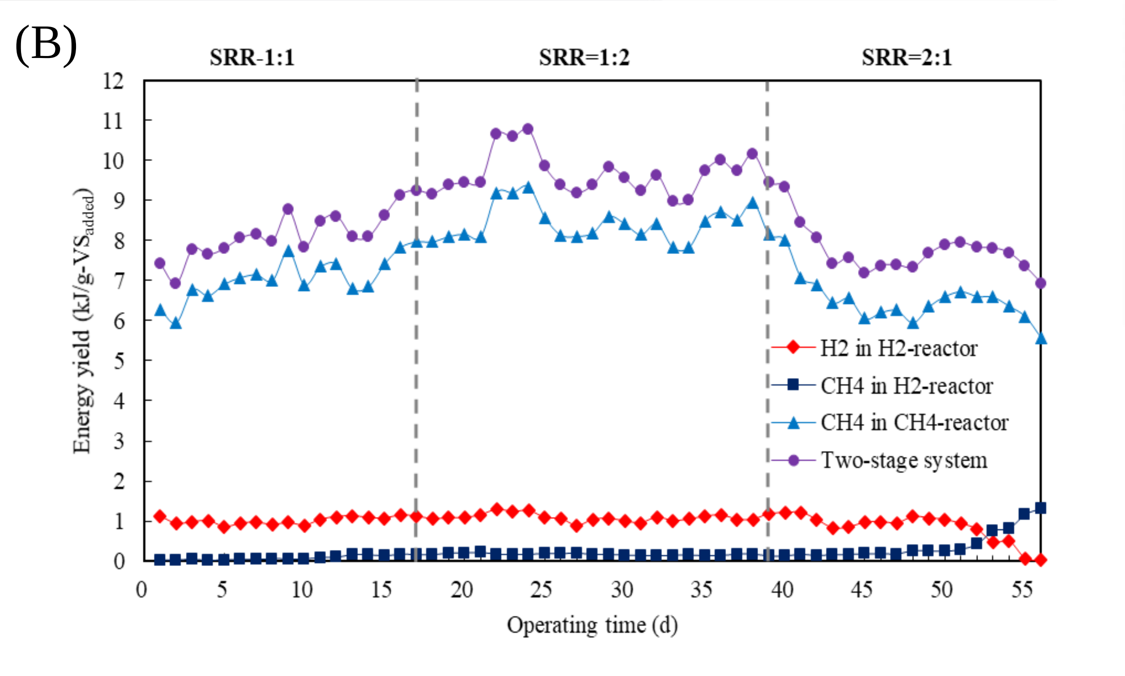
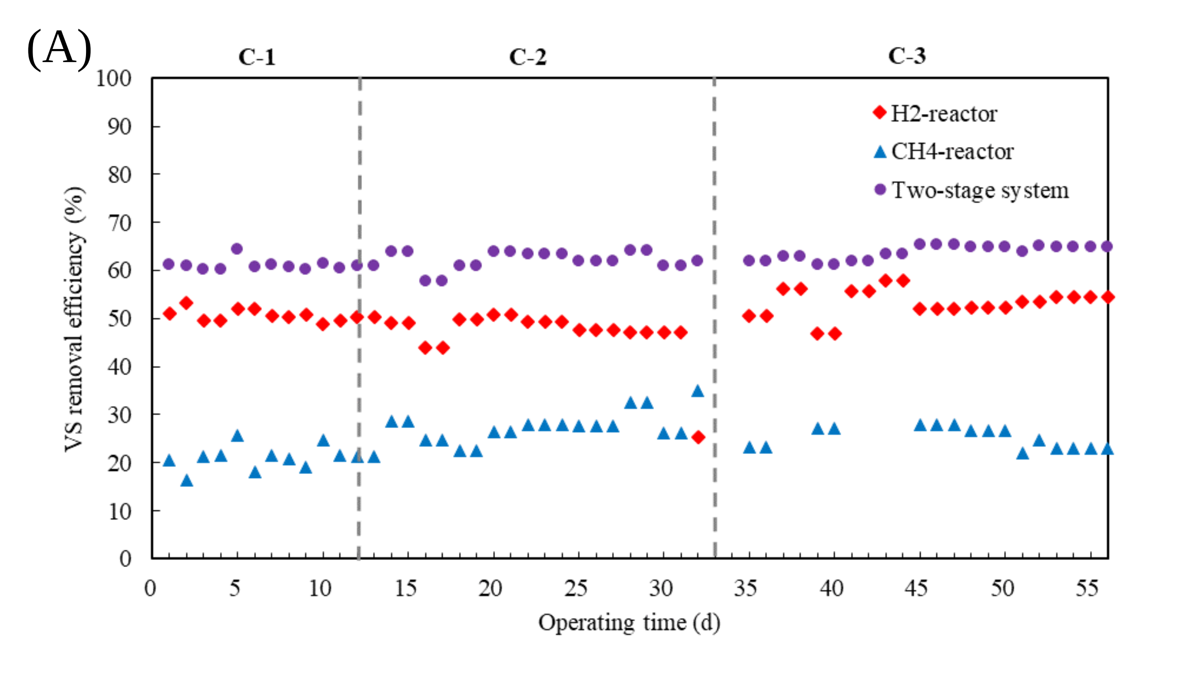




**Fig. 3** Energy yields of $H_2$-reactor, $CH_4$-reactor and total energy yields of the two-stage system with different M-SRT (A) and SRR (B).

Moderate methanogens in $H_2$-reactor might promote energy yields of the two-stage system.

Excessive methanogens might affect the stability of $H_2$-reactor and inhibit the operation of two-stage system.

# Results and discussion: VS removal efficiency



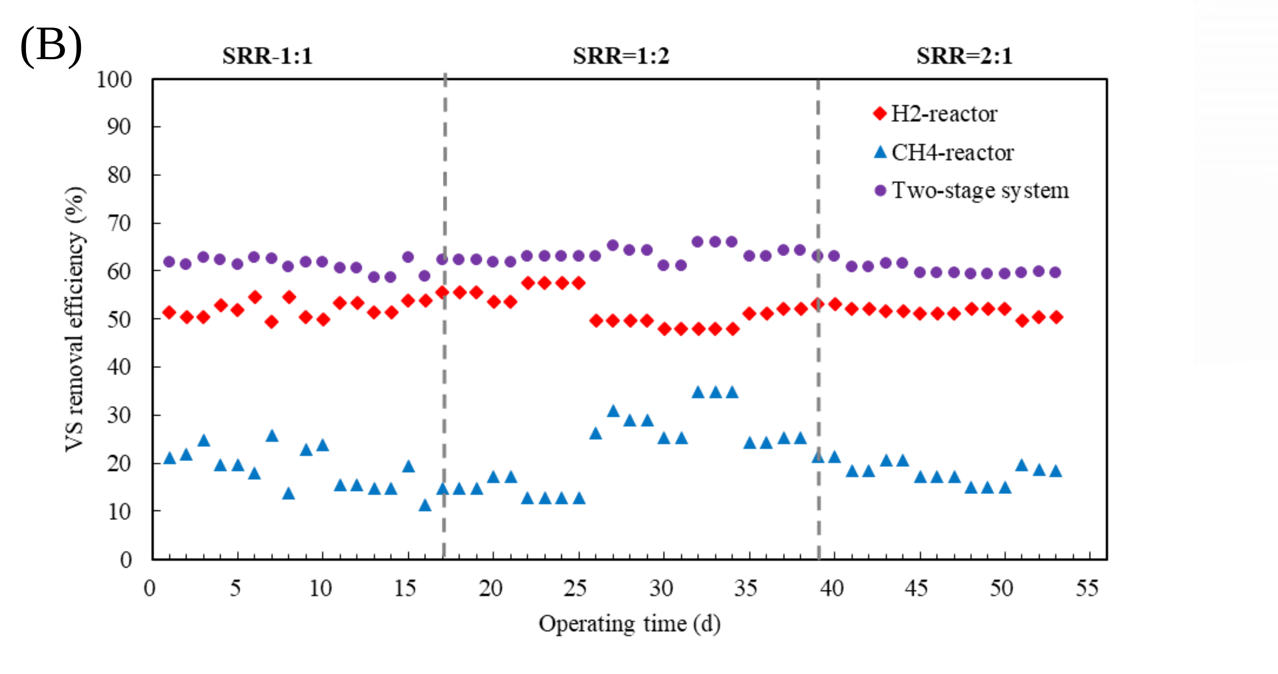




**Fig. 4** VS removal efficiency of discharged sludge from $H_2$-reactor and $CH_4$-reactor, total VS removal efficiency of the two-stage system with different M-SRT (A) and SRR (B).

Higher M-SRT promoted the degradation of organics slightly in the two-stage system.

Temperature-separated two-stage anaerobic fermentation system performed better than temperature-separated methanogenic stage system.

# Results and discussion: Microbial analysis

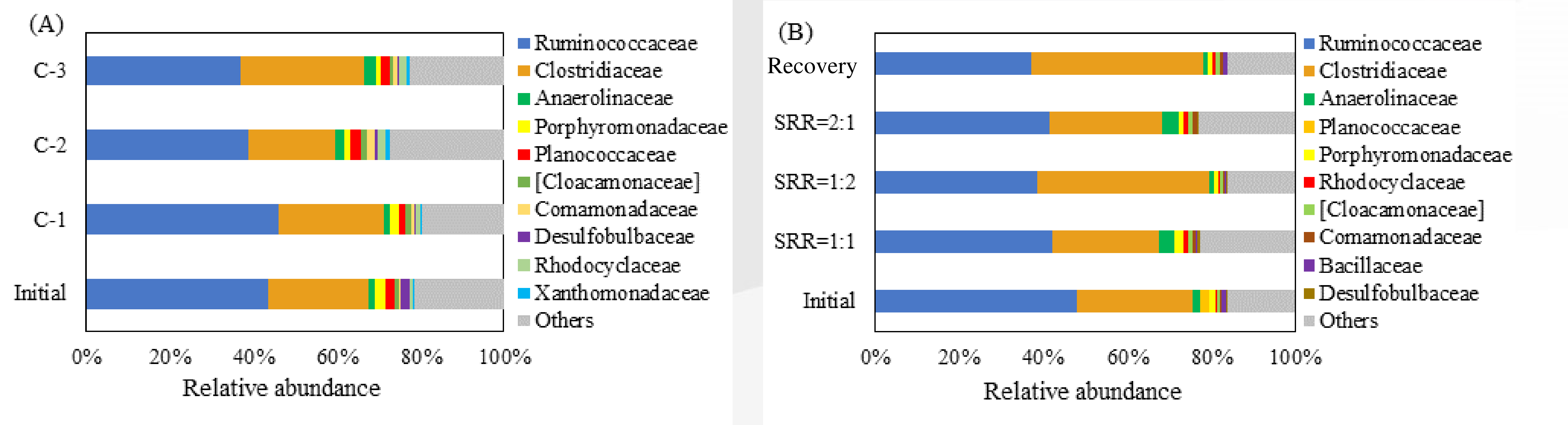



**Fig. 5** Relative sequence abundances of discharged sludge samples from $H_2$-reactor at the family level under different M-SRT (A) and SRR (B).

Dominant bacterial families: *Ruminococcaceae* and *Clostridiaceae*.

***Clostridia***

# Results and discussion: Microbial analysis

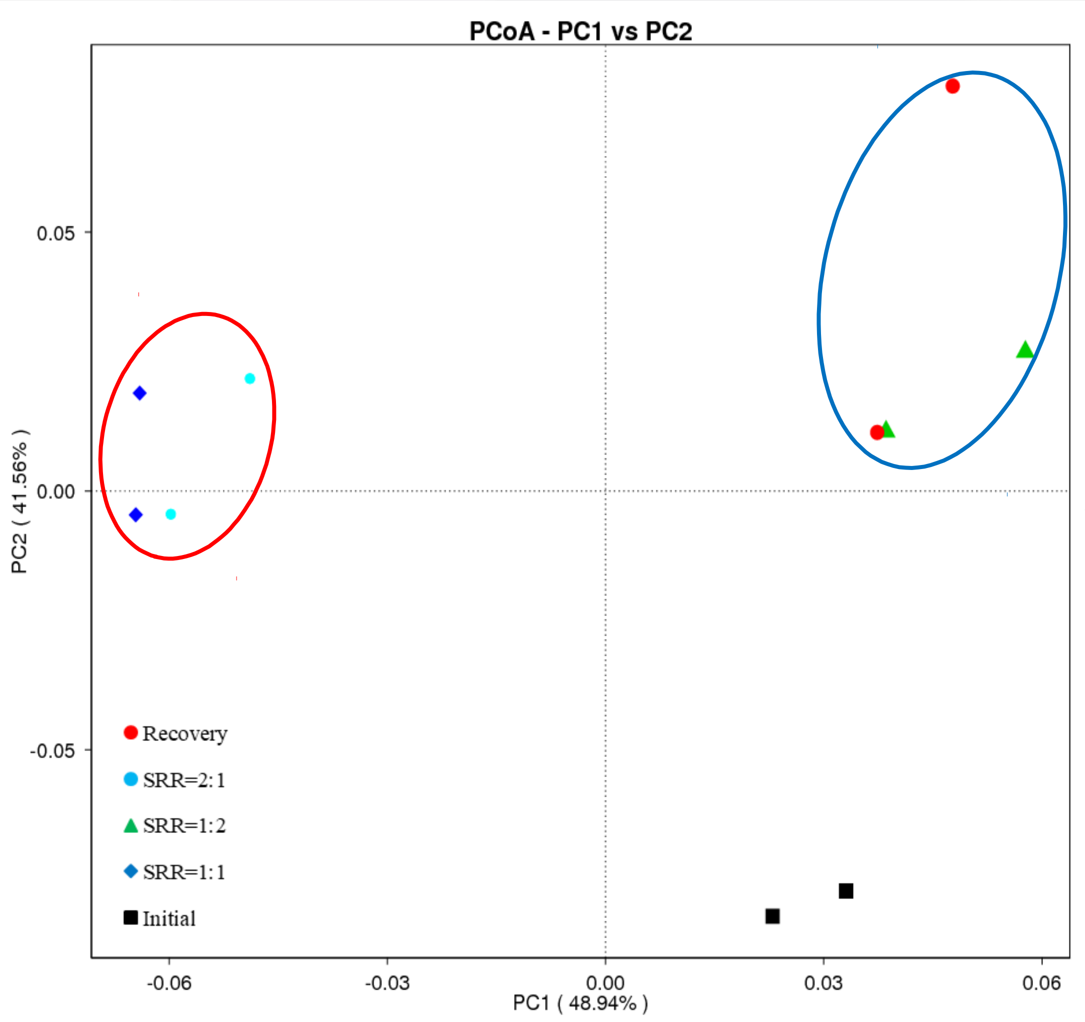



**Fig. 6** Principal Coordinates Analysis (PCoA) of discharged sludge samples from $H_2$-reactor under different SRR.

**Optimized SRR: 1:1**
Considering the economic cost of external alkalinity as well as running effect

**Table 2** Average alkali dosage with different M-SRT and SRR.

| Operating condition | Average alkali dosage (g/L/d) |
|---|---|
| C-1 | 0.791 |
| C-2 | 0.922 |
| C-3 | 1.640 |
| SRR=1:1 | 1.331 |
| SRR=1:2 | 2.206 |
| SRR=2:1 | 0.000 |

# Conclusions

**Optimized M-SRT: 12 d**

- Higher M-SRT improved the removal of organics and energy yield of the system
- Higher M-SRT reduced the stability of hydrogen production in $H_2$-reactor, but in this study, all the M-SRT conditions were below the threshold level.

**Optimized SRR: 1:1**

- Return sludge could complement alkalinity for acidogenic stage
- Methanogens in return sludge inhibited $H_2$ production and caused stage transfer in $H_2$-reactor, which influenced the operation of two-stage system eventually.

THANKS!