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

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Background information

WASTE ACTIVATE D SLUDGE
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Table 1 Operating conditions of different periods in the two-stage anaerobic fermentation process.

<table>
<thead>
<tr>
<th>Operating condition</th>
<th>H2-reactor</th>
<th>CH4-reactor</th>
<th>Operating time (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>1</td>
<td>30.8</td>
<td>4</td>
</tr>
<tr>
<td>C-2</td>
<td>1</td>
<td>30.3</td>
<td>8</td>
</tr>
<tr>
<td>C-3</td>
<td>1.2</td>
<td>27.4</td>
<td>12</td>
</tr>
<tr>
<td>SRR=1:1</td>
<td>1</td>
<td>30.6</td>
<td>4</td>
</tr>
<tr>
<td>SRR=1:2</td>
<td>1</td>
<td>26.9</td>
<td>4</td>
</tr>
<tr>
<td>SRR=2:1</td>
<td>1</td>
<td>34.3</td>
<td>4</td>
</tr>
</tbody>
</table>

M-SRT
Sludge retention time of methane producing stage

SRR
sludge return ratios of the system
Results and discussion: Biogas production

**Fig. 2** Production rate of $\text{H}_2$, $\text{CO}_2$ and $\text{CH}_4$ in $\text{H}_2$-reactor with different M-SRT (A) and SRR (B).

$\text{H}_2$ production in $\text{H}_2$-reactor could be promoted by properly prolonging M-SRT.
Results and discussion: Biogas production

Fig. 2 Production rate of $\text{H}_2$, $\text{CO}_2$ and $\text{CH}_4$ in $\text{H}_2$-reactor with different M-SRT (A) and SRR (B).

- **SRR=2:1**
  - collapse of $\text{H}_2$ production
  - Added sodium 2-bromoethanesulphonate (BESA)
  - recovery of $\text{H}_2$ production

The stage in $\text{H}_2$-reactor transferred from acidogenic stage to methanogenic stage with higher SRR.
Results and discussion: Energy yield

Fig. 3 Energy yields of H₂-reactor, CH₄-reactor and total energy yields of the two-stage system with different M-SRT (A) and SRR (B).

Moderate methanogens in H₂-reactor might promote energy yields of the two-stage system.

Excessive methanogens might affect the stability of H₂-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\textsubscript{2}-reactor and CH\textsubscript{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 H₂-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 H₂-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.

<table>
<thead>
<tr>
<th>Operating condition</th>
<th>Average alkali dosage (g/L/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>0.791</td>
</tr>
<tr>
<td>C-2</td>
<td>0.922</td>
</tr>
<tr>
<td>C-3</td>
<td>1.640</td>
</tr>
<tr>
<td>SRR=1:1</td>
<td>1.331</td>
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<tr>
<td>SRR=1:2</td>
<td>2.206</td>
</tr>
<tr>
<td>SRR=2:1</td>
<td>0.000</td>
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</table>
Conclusions

- Higher M-SRT improved the removal of organics and energy yield of the system
- Higher M-SRT reduced the stability of hydrogen production in H₂-reactor, but in this study, all the M-SRT conditions were below the threshold level.

Optimized M-SRT: 12 d

- Return sludge could complement alkalinity for acidogenic stage
- Methanogens in return sludge inhibited H₂ production and caused stage transfer in H₂-reactor, which influenced the operation of two-stage system eventually.

Optimized SRR: 1:1
THANKS!