Enzymatic pretreatment of organic residual solids for anaerobic digestion

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UK (2016): 15,734,000 tonnes to landfill
49% was biodegradable

2025 objective?
Biorefinery products

ORS 18,700 tonnes -2,240,000£
Anaerobic digestion

- WASTE
  - Carbohydrates
  - Proteins
  - Lipids

- SOLUBLE MOLECULES
  - Sugars
  - Amino acids
  - Fatty acids

- Alcohols
- Carbonic acids
- Volatile fatty acids

- Methanogenesis
  - Acetic acid
  - CH$_4$
  - CO$_2$
  - H$_2$
  - CO$_2$
  - NH$_3$
  - NH$_4$
  - H$_2$S

Hydrolysis

Acidogenic fermentation
Anaerobic digestion

Advantages
- Mature technology
- Single end-product
- In situ product recovery
- Absence of product inhibition
- Thermodynamically favourable
- Mild conditions -> environmentally friendly.

Drawbacks
- CH4 global warming potential = 23x CO2 potential
- Reactor instability
- Economically unfeasible without subsidies (0.4 €/kg)

Acidogenic fermentation

- Organic Matter → VFAs
- PHAs 2.0 €/kg
- Lipids for biodiesel
- Microbial fuel cells
- Biogas 0.4 €/kg

Faster process – more economic!
ORS composition
Pretreatments

**Chemical**
Oxydative reactions: Ozonation, alkali and acid pretreatments, etc.
- Effective
- Toxic compounds generation/expensive

**Physical**
Thermal treatments, microwaves, ultrasound, etc.
- Effective
- High energy consumption/expensive

**Biological**
Use of biological agents such as microorganisms or enzymes
- Effective/Environmentally friendly
- Complex treatment (specific to substrate)
- Economic solution
5% enzyme loading, 17h at 50°C, 1.6% TS

**Complex A:** cellulase/β-glucosidase/hemicellulase

**Complex B:** cellulase/β-glucanase/hemicellulase/xylanase/arabinase
Pretreatment – batch experiments

17h at 50°C, 0.2% TS
Pretreatment prior to AD

5% enzyme loading
50°C for 24h, 6.8% TS
Semi continuous AD

HRT=14 days
OLR=3.5 g VS/L day

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<tr>
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<th>AD</th>
<th>Enzyme pretreatment + AD</th>
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<tbody>
<tr>
<td>Cost of landfill (£/tonne ORS)</td>
<td>107.00</td>
<td>88.72</td>
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<tr>
<td>Cost of enzyme (£/tonne ORS)</td>
<td>0.00</td>
<td>40.21</td>
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<tr>
<td>Benefits from CH4 (£/tonne ORS)</td>
<td>11.63</td>
<td>13.71</td>
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<td>Balance (£/tonne ORS)</td>
<td>-95.37</td>
<td>-115.22</td>
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Conclusions

Enzymatic pretreatment with carbohydrates complex improved methane yield by 18%.

Under the tested conditions, AD + enzymatic pretreatment is not an economic solution.

ORS could be better suited for a VFA factory.

Future work

Influence of pH and other variables on VFA production.

DOE for enzymatic pretreatment and subsequent acidogenic fermentation.

Dewaterability tests and separation methods.
Thank you

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Gracias

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