Butanol for sustainable aviation

Sustainable Aviation Fuel - Workshop
20.11.2018

Dr. Helena Junicke
heljun@dtu.dk

DTU Chemical Engineering
Department of Chemical and Biochemical Engineering
Outline

Introduction
  – Alternative jet fuel pathways
  – Alcohol-to-jet

Opportunities for butanol
  – Butanol from waste
  – The GreenLogic project

Methods and results
  – Continuous enrichment studies
  – Thermodynamic system design
  – Modelling of full-scale reactors

Conclusions

Outlook
# Alternative jet fuel pathways

- There are five ASTM D7566 certified pathways for synthetic paraffinic kerosene (SPK) production

<table>
<thead>
<tr>
<th>Type</th>
<th>Pathway</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas-to-jet</td>
<td>FT-SPK</td>
<td>SPK from syngas via Fischer-Tropsch (FT)</td>
</tr>
<tr>
<td></td>
<td>FT-SPK/A</td>
<td>FT-SPK with increased aromatic content</td>
</tr>
<tr>
<td>Oil-to-jet</td>
<td>HEFA-SPK</td>
<td>SPK from hydro-processed esters and fatty acids (HEFA)</td>
</tr>
<tr>
<td>Sugar-to-jet</td>
<td>SIP-SPK</td>
<td>Synthesized iso-paraffins (SIP) obtained via farnesene intermediate</td>
</tr>
<tr>
<td>Alcohol-to-jet</td>
<td>ATJ-SPK</td>
<td>SPK from C2-C5 alcohols</td>
</tr>
</tbody>
</table>

FOCUS

The alcohol-to-jet pathway

Energy crops

Cellulosic materials

Fermentation

(bio)chemical pretreatment

Dehydration

Oligomerization

Hydrogenation

Distillation

ATJ (C8-C16)

Opportunities

- ASTM D7566-18 permits blending iso-butanol and ethanol derived SPK with conventional jet fuels of up to 50%
- Sourcing C2-C5 alcohols from waste

Non-competition with food production  
Cheap feedstock  
Closing the circular economy gap  
Energy recovery
Butanol from waste – How?

- Anaerobic mixed microbial cultures
- Non-standard conditions (pH 5, increased pH\textsubscript{2})

The GreenLogic project

- Production of **C2-C5 alcohols** from industrial and municipal waste streams
- Upgrading waste water treatment plants (WWTP) into water **resource recovery** facilities (WRRF)

Waste streams → Clean water → Biogas → Liquid biofuels
Anaerobic digestion: The classical view

Polymers
carbohydrates, proteins, lipids

Monomers
monosaccharides, amino acids, LCFA

Short-chain fatty acids
propionate, butyrate, ...

Hydrolysis

Acidogenesis

Acetogenesis

Methanogenesis

Current focus
Different microbial groups degrade complex waste streams into biogas.

H₂

Acetate

CH₄ + CO₂
Anaerobic digestion: Butanol enrichment

- **Hydrolysis**
  - Polymers: carbohydrates, proteins, lipids

- **Acidogenesis**
  - Monomers: monosaccharides, amino acids, LCFA
  - Short-chain fatty acids: propionate, butyrate, ...

- **Solventogenesis**
  - C2-C5 alcohols

**New focus**
Operate at pH 5 and high pH$_2$ to promote alcohol formation.

- $\text{H}_2 + \text{Butyrate} \rightarrow \text{Acetate} + \text{H}_2$
- Acetate $\rightarrow \text{CO}_2 + \text{CH}_4$
- Butanol
- CO$_2$ + H$_2$ $\rightarrow$ CH$_4$
Thermodynamic system design

- Unlocking butanol formation
- Increase $H_2$, decrease pH (see arrow)

Butanol formation
\[ \text{Butyrate}^- + H^+ + 2H_2 \rightarrow \text{Butanol} + H_2O \]

\[
\Delta G^1 < 0 \\
\Delta G^1 = 0 \\
\Delta G^1 > 0
\]
Modelling of full-scale anaerobic digesters

- From biogas towards butanol formation

Confidential information on this slide has been removed.
Conclusions

• **Butanol production** from waste under non-standard conditions

• **Mixed culture biotechnology** as a solution for cheap feedstock conversion into ATJ-SPK

• ATJ-SPK approval for C3-C5 alcohols expected in the **mid-term**; ethanol and iso-butanol are certified already
Outlook

- Techno-economic analysis of upstream (H₂ and butyrate sources) and downstream processing

- Enrichment of new biocatalysts for butanol formation (microorganisms, enzymes)

- Municipal and industrial waste streams as cheap and sustainable feedstock for jet fuel production
Thank you for your attention!

Project partners: