Butanol for sustainable aviation

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Publication date: 2018

Document Version: Peer reviewed version

Citation (APA):

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Butanol for sustainable aviation

Sustainable Aviation Fuel - Workshop
20.11.2018

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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>
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<tr>
<td>Gas-to-jet</td>
<td>FT-SPK</td>
<td>SPK from syngas via Fischer-Tropsch (FT)</td>
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<tr>
<td></td>
<td>FT-SPK/A</td>
<td>FT-SPK with increased aromatic content</td>
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<tr>
<td>Oil-to-jet</td>
<td>HEFA-SPK</td>
<td>SPK from hydro-processed esters and fatty acids (HEFA)</td>
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<tr>
<td>Sugar-to-jet</td>
<td>SIP-SPK</td>
<td>Synthesized iso-paraffins (SIP) obtained via farnesene intermediate</td>
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<tr>
<td><strong>Alcohol-to-jet</strong></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
Municipal & Industrial waste streams

Fermentation
(bio)chemical pretreatment

Alcohols
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$_2$)


Surplus electricity

Butyrate and H$_2$: typical intermediates
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)

![Diagram of waste streams processing into liquid biofuels, biogas, and clean water](image)

- Liquid biofuels
- Biogas
- Clean water
Anaerobic digestion: The classical view

- **Polymers**
  - carbohydrates, proteins, lipids

- **Monomers**
  - monosaccharides, amino acids, LCFA

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

Current focus:

Different microbial groups degrade complex waste streams into biogas.

- Hydrolysis
- Acidogenesis
- Acetogenesis
- Methanogenesis

\[ \text{CH}_4 + \text{CO}_2 \]
**Anaerobic digestion: Butanol enrichment**

- **Polymers**
  - carbohydrates, proteins, lipids

- **Monomers**
  - monosaccharides, amino acids, LCFA

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

- **C2-C5 alcohols**

**New focus**

Operate at **pH 5 and high pH₂** to promote alcohol formation.

- $\text{H}_2 + \text{Butyrate} \rightarrow \text{Acetate} + \text{H}_2$
- $\text{Acetate} \rightarrow \text{CO}_2 + \text{CH}_4$
- $\text{CO}_2 + \text{H}_2 \rightarrow \text{CH}_4$

**Operational Processes**

- **Hydrolysis**
  - Polymers → Monomers
  - Monomers → Short-chain fatty acids
  - Short-chain fatty acids → C2-C5 alcohols

- **Acidogenesis**

- **Solventogenesis**
Thermodynamic system design

- Unlocking butanol formation
- Increase H₂, decrease pH (see arrow)

Butanol formation
Butyrate⁻ + H⁺ + 2H₂ → Butanol + H₂O

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

• From biogas towards butanol formation
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: