Towards the production of biopolymers from syngas at commercial scale
9th September 2016
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   - Methods to overcome limitations

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3. Prospects
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Products from biological fermentation from syngas

Acetate
Butyrate
Long chain fatty acids
Ethanol
Propanol
Butanol
2,3-butanediol
Hydrogen
Acetone
Mevalonate
PHB-HV

Advantages of bacteria as biocatalysts

- Mild operation T and P conditions
- Output of products less sensitive to CO/H2 ration
- The water-gas shift that produces H2 is implicit in the metabolism of autotrophic and unicarboxytrrophic anaerobes
- Less sensitivity to trace amounts of contaminants in the syngas
- Product specific
- Uncoupling the hydraulic retention time from the substrate supply: control substrate inhibition and product formation
- The direct production of polymers is possible

Limitations of fermentation processes

- Slow bacterial cellular growth
- Low solubility of CO and H2 in aqueous phase
- Low rates of bioproduction: metabolic pathways modifications
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Methods to enhance chemicals production:

- Media optimization
- Reactor design
- Genetic modifications

The Synpol platform (www.synpol.org)
## Companies that employ syngas as feedstock for the production of commodities at pilot and/or industrial scale

<table>
<thead>
<tr>
<th>Company</th>
<th>Feedstock</th>
<th>Product</th>
<th>Current status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coskata Inc., USA</td>
<td>Natural gas, industrial gases, coal, residual biomass and waste / gasification</td>
<td>Ethanol Lab scale: propanol, butanol, butanediol, hexanol, organic acids and fatty acids</td>
<td>Out of business in 2015 Re-merged as Synata bio</td>
</tr>
<tr>
<td>INEOS Bio, Switzerland</td>
<td>Lignocellulosic biomass and organic waste /gasification</td>
<td>Ethanol</td>
<td>Getting out of ethanol business</td>
</tr>
<tr>
<td>LanzaTech Inc., USA</td>
<td>Efluent waste gas from steel mills and coal producers; woody biomass to syngas/gasification</td>
<td>Ethanol, 2,3-BD</td>
<td>In business</td>
</tr>
</tbody>
</table>

Daniell *et al.*, (2012), *Energies*, 5, 5372-5417
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<tr>
<td>BioMethanolChemie Nederland B.V., The Netherlands</td>
<td>Biogas, glycerine/gasification</td>
<td>Methanol</td>
<td>Operates as a subsidiary of OCI N.V.</td>
</tr>
<tr>
<td>SyngasBiofuelsEnergy Inc., USA</td>
<td>Air CO2 and H2/water electrolysis</td>
<td>Butanol/Isobutanol</td>
<td>Seems to be still in business</td>
</tr>
<tr>
<td>BRI Energy Inc. USA</td>
<td>MSW, agriculture and animal wastes, coal/gasification</td>
<td>Ethanol and electricity</td>
<td>Pilot unit from 2003, acquired by Ineos in 2008</td>
</tr>
<tr>
<td>OPX Biotechnologies Inc., USA</td>
<td>No info available</td>
<td>Fatty acids</td>
<td>Acquired by Cargill in 2015</td>
</tr>
</tbody>
</table>

Daniell et al., (2012), *Energies*, 5, 5372-5417
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Coskata Inc.

www.coskata.com
Coskata Inc.

Founded in 2006 in Warrenville, IL, USA
### Microorganisms

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<tr>
<th>Microorganisms</th>
<th>Bioreactors</th>
<th>Production capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. carboxidivorans</em></td>
<td>Patented immobilised fibre membranes (gas direct contact with organism)</td>
<td>Demo plant in Madison, PA</td>
</tr>
<tr>
<td><em>C. ragsdalei</em></td>
<td></td>
<td>Commercial plant in Alabama</td>
</tr>
<tr>
<td><em>C. coskatii</em></td>
<td></td>
<td>60 million liters of ethanol per year, to be scaled up to 295 million liters of ethanol per year</td>
</tr>
<tr>
<td>Improved strains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>through mutagenesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and clonal <strong>screening</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Strains licensed from Oklahoma State University and the University of Oklahoma**

*C. ljungdahlii* mutant strain *OTA-1* has been isolated that produces approximately 2-fold more ethanol than the wt

Coskata’s technology re-emerges as Synata Bio

Jim Lane  24/1/2016

In Illinois, the technology formerly belonging to Coskata has re-merged as the newly-minted Synata Bio, which was formed last year.

Synata filed a Red D form with the Securities & Exchange Commission, detailing a $10 million investment, which sources have identified as coming from True North Venture Partners. Sure enough, True North partners Matthew Ahearn and Steve Kloos are listed as directors of the firm, along with long-time industry scientific guru Jay Koubab, last himself seen running another natgas-oriented business, Trelis, which itself has attracted investment from ARCH Venture Partners and FirstGreen Partners. Koubab has also had roles with Amoco, BP, Metabolix, Virent, TetraVita, and Siluria. Kloos is currently serving as Synata’s President.

Coskata had been focused, via gas fermentation, on converting natural gas to fuels. We suspect that, given low oil prices, Synata Bio may steer that technology towards attractive opportunities in chemicals. Possibly acetic acid, propanol or n-butanol.

The filing lists the company address as “4575 Weaver Parkway, Suite 100, Warrenville, IL, Illinois, 60555”, which long-time observers will recognize as the former Coskata headquarters. Sources have also told The Digest the as much as “half of the old Coskata scientific staff” have been hired on by Synata Bio to continue the company’s research. Sources also indicated that Synata acquired the Coskata technology.

http://www.biofuelsdigest.com/bdigest/2016/01/24/coskatas-technology-re-emerges-as-synata-bio/
Ineos Bio

http://www.ineos.com/businesses/ineos-bio
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**Ineos Bio**

Commercial demonstration facilities

Indian River Bioenergy Center in Florida
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Ineos Bio
Ineos Bio

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<tbody>
<tr>
<td>Proprietary isolates of <em>C. ljungdahlii</em></td>
<td>Two stage CSTR system</td>
<td>300 dry tons of feedstock per day; producing 30 million liters of ethanol per year</td>
</tr>
<tr>
<td>Methods for Increasing the Production of Ethanol from Microbial Fermentation US 20120122173 A1</td>
<td></td>
<td>6MW of electricity of unused syngas and recovered heat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A second commercial plant, Seal Sands in the UK is planned</td>
</tr>
</tbody>
</table>

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Ineos Bio to sell ethanol business, including Vero Beach plant

By Erin Voegele | September 07, 2016

Ineos Bio has announced its intent to sell its ethanol business, including the Ineos New Planet BioEnergy demonstration plant in Vero Beach, Florida, and the Ineos Bio USA Research Center in Fayetteville, Arkansas, via a bid process targeting year end completion. The company said it has received expressions of interest from a number of potential suitors, is progressing negotiations, and hopes to make a decision on bidders and sale by the end of the year.

In a statement, Ineos Bio said the U.S. market for ethanol has changed and the economic drivers for development of the technology by Ineos are no longer aligned with the company’s strategic objectives. As a result, the company intends to sell its ethanol business.

The statement also indicates Ineos spent more than eight years and $300 million developing and commercializing its cellulosic technology. “The Vero Beach demonstration plant has achieved continuous operations and commercial scale syngas fermentation and has been instrumental in identifying various process improvements to be incorporated into the design and construction of the next generation of bioethanol plants based on the technology,” said the company.

LanzaTech

Novel gas fermentation technology captures CO-rich gases and converts the carbon to fuels and chemicals.

www.lanzatech.com
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LanzaTech
LanzaTech

1 organism, 20 products... so far!

Physiology
- Shift Ethanol: BDO ratio (BDO KO)
- Ethanol tolerance
- Vitamin biosynthesis
LanzaTech

Alcohol to Jet (ATJ) Pathway

A novel route to synthetic jet fuel
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### LanzaTech

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<tr>
<td>Proprietary strain of <em>C. autoethanogenum</em></td>
<td>CSTRs Improvements on carbon capture for fermentation Patent E08843491 (5)</td>
<td>BlueScope steel facility in New Zealand since 2008</td>
</tr>
<tr>
<td>In-house synthetic biology capability</td>
<td></td>
<td>Pre-commercial 380,000 liters of ethanol per year in partnership with BaoSteel in China</td>
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<td></td>
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<td>Demonstration plant at Shoungang stell mill (China)</td>
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<td></td>
<td></td>
<td>Range Fuels plant in Soperton, Georgia (syngas from wood residues)</td>
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<td></td>
<td>Taiwan Demo plant</td>
</tr>
</tbody>
</table>

No commercial facilities in Europe

No patent applications for the production of biopolymers using syngas

Still a long way to have cost-effective processes

New tools for improvement: genetic tools and systems biology

Projects such as Synpol provide great advances towards viable syngas utilization processes

Success is possible!!!
Thank you very much for your attention!!