NexantECA

Technology and Costs

Biorenewable Insights: Syngas Fermentation

Syngas Fermentation is one in a series of reports published as part of NexantECA's 2024 Biorenewable Insights program.

Overview

A number of species of organisms in nature are known to subsist partially or entirely on mixtures of hydrogen and carbon dioxide that are also common feedstocks for chemical synthesis. Although these organisms are generally regarded as having primitive pathways in comparison to other types of bacteria and to eukaryotic organisms, such as yeasts and higher plants (in the sense of evolutionary fitness), prokaryotic bacteria utilizing hydrogen-CO2 mixture are surprisingly common in the environment, subsisting in environments as varied as soil, hot springs, the guts of animals, and deep sea vents.

In recent years, these gas-fermenting organisms have attracted considerable interest from commercial developers of alternative fuels, bio-based chemicals, and foods and feeds. Although these organisms pose considerable process challenges, they offer attractive potential economics due to the low cost of feedstock and their inherent tolerance to dilute gaseous feedstocks and many types of impurities, notably sulfur compounds that would otherwise have to be removed before being used in a petrochemical process.

Technologies

The overwhelming concern in gas fermentation is mass transfer. Gas-liquid mass-transfer is a well-studied problem in a variety of contexts, but with gas fermentations the problem is particularly acute due to the low solubility of non-polar feedstock molecules in the (polar) water that makes up the vast majority of the medium that must be used for fermentative growth.

As the gases must be dissolved in solution to be accessible to the fermentative organisms, the low solubility levels limit the effective rate of fermentation by bounding the maximum concentration of the gas in solution. It also follows that high concentrations of gases fed into the reactor will remain in the gas phase until the gases already dissolved are consumed. Consequently, gas-liquid mass transfer in a gas fermentation bioreactor requires:

- Ensuring sufficient gas-liquid contact for mass transfer to occur
- Ensuring sufficiently long residence time for gases in the reactor such that the majority of fermentable gases are absorbed and consumed

The two classic fermenter designs in gas fermentations are continuous stirred tank reactors and bubble column/airlift reactors. Other designs being investigated are hollow fiber reactors, trickle bed reactors, and moving bed biofilm reactors.

Technology for syngas fermentation from the following developers are discussed:

- LanzaTech – Ethanol and 2,3-BDO and several others in development
- Synata Bio – Ethanol
- INEOS Bio – Ethanol
- Kiverdi – Mid-to-long chain fatty acids, protein, oils and other oleochemical products

Process Economics

Cost of production models for USGC, Brazil, Western Europe and China are shown for selected technology developers.

Carbon Intensity

Carbon intensity analysis and commentary covering scope 1 and scope 2 emissions are covered for the main syngas fermentation technology developers.

Commercial

NexantECA has catalogued existing and planned commercial syngas production capacity.

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Technology and Costs comprises the Technoeconomics – Energy & Chemicals (TECH) program, the Biorenewable Insights program (BI), and the new Cost Curve Analysis. These programs provide comparative economics of different process routes and technologies in various geographic regions.

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