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Syngas Fermentation

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Abstract

Syngas fermentation is a bioconversion technology of syngas/waste gas components to produce low-carbon biofuels. This technology is currently undergoing an intensive research and development phase. The fermentation process depends on the use of a microorganism called acetogen that generates acetate as a product of anaerobic repiration. Acetogens are found in a variety of habitats, generally those that are anaerobic. Acetogens can use a variety of compounds as sources of energy and carbon; the best-studied form of acetogenic metabolism involves the use of carbon dioxide as a carbon source, and hydrogen as an energy source.

A number of laboratory- and demonstration-scale studies have been done on the subject of using acetogens that have the ability to convert various synthesis gas (syngas) components (CO, CO_2, and H_2) to multicarbon compounds such as ethanol, 2,3-butanediol, acetate, butyrate, butanol, and lactate. At present, ethanol is the most noteworthy final product, followed by 2,3-butanediol. This bioconversion process occurs under mild conditions of temperature and pressure. Unlike conventional thermochemical processes, it does not require a specific H_2:CO ratio for converting the gas into fuels and chemicals.

Syngas fermentation technology is still in the commercializing stage. Several aspects affecting product output and yield are under constant review for improvements and refinements. Some of the noteworthy parameters that are a focus of research for ethanol and 2,3-butanediol production include yield, biological catalysts, process kinetics, mass transfer, catalytic separation, materials recycling/reusing, etc.

The objective of this report is to examine the abovementioned fermentation technologies, to evaluate their economics, and to offer a financial impact assessment on the economics resulting from variations in those process parameters.

In this report, we present a critical review of CO-rich gas fermentation processes to produce ethanol and 2,3-butanediol. We also present a comprehensive description of the fermentation product impurities, microorganisms, chemical reactions, separation techniques, bioreactor types, fermentation conditions, gas–liquid mass transfer, current industry status, process scale-up, and future directions for the technology. Further, we offer an analysis of LanzaTech technology; LanzaTech, a revolutionary carbon recycling company, is a major player in the developing syngas fermentation market, and has made big announcements recently about the commercialization of its technology.

The following cases are covered in this report:

1. Case I—LanzaTech syngas fermentation using biomass syngas, producing anhydrous ethanol.

2. Case II—LanzaTech syngas fermentation using biomass syngas, producing anhydrous ethanol as well as 2,3-butanediol.

3. Case III—LanzaTech syngas fermentation using steel mill waste gases, producing anhydrous ethanol.

We have used Aspen Plus™ and IHS internal tools to work out a process design and its economics. While the challenges associated with the scale-up and operation of this novel process remain with the selection of

proper feedstock and variable product prices, syngas fermentation offers numerous advantages compared with the established fermentation or conventional thermochemical approaches for biofuel production. This process is capable of producing multiple products from the same gas stream and same hardware. The technology is feedstock-flexible, and microbial catalyst can utilize a range of gases with different H_2:CO composition while retaining product specificity.

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