U.S. DEPARTMENT OF
ENERGY

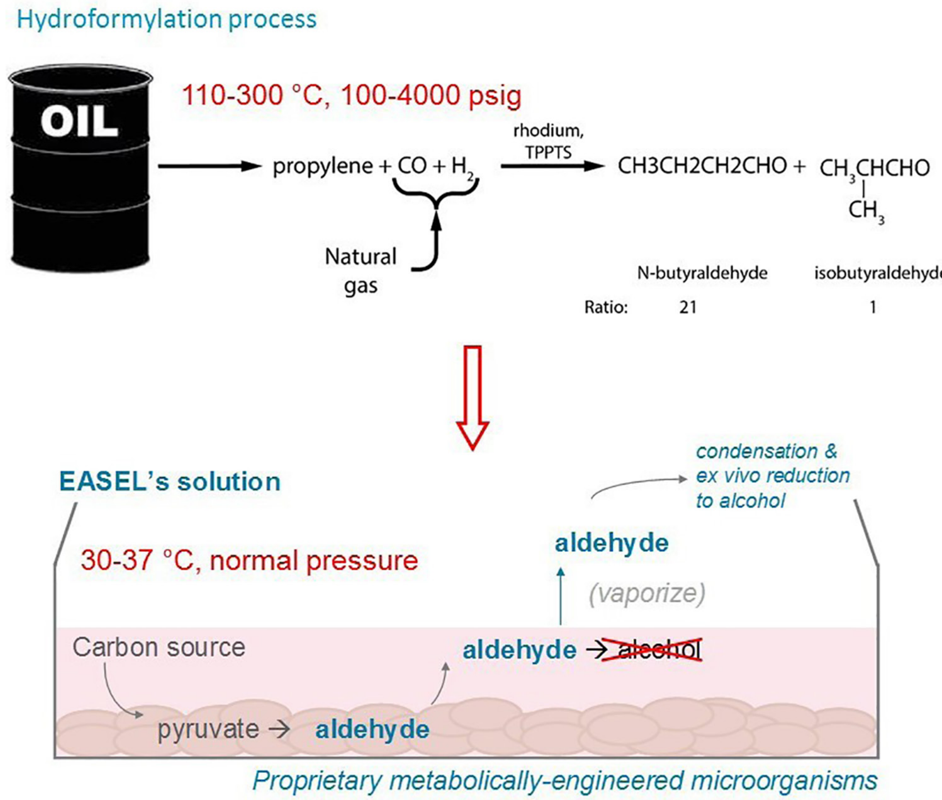
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Bio-Oxo Technology

Enabling production of commodity chemicals from renewable resources

Aldehydes are important intermediate chemicals used in a wide array of industrial and consumer products, including plasticizers, fine chemicals, and pharmaceuticals. The oxo process, also called hydroformylation, is used to make aldehydes by adding a mixture of carbon monoxide and hydrogen to an olefin. Currently, more than 10 million metric tons of aldehydes are produced by hydroformylation using petroleum-derived propylene and a significant expenditure of energy due to the high temperature and pressure conditions required for production. In addition, these oxo chemical processes all require energy intensive distillation processes to separate the mixture of aldehydes produced.

Researchers made good progress in developing a more energy efficient bio-oxo process that takes advantage of the carbon-carbon bond formation innate to microorganisms to produce pure isobutyraldehyde, a commercially valuable aldehyde used in consumer products such as lube oil additives, surface coatings, plasticizers, fertilizers, cosmetics, herbicides, flame retardants, and adhesives. The bio-oxo process uses innovative, metabolically-engineered bacteria to convert renewable resources to isobutyraldehyde via low-temperature, energy-efficient processes. The technology takes advantage of the product's low boiling point and vapor pressure to use an energy efficient gas-stripping process to collect and purify the target product. This process also reduces the exposure of the organisms to the product while increasing initial yield, making the entire system significantly more sustainable than other biological processes used to produce chemicals.



Proposed Bio-oxo process will produce isobutyraldehye (aldehyde) using proprietary metabolically engineered microorganisms. *Photo credit Easel Biotechnologies.*

Benefits for Our Industry and Our Nation

The bio-oxo process is much more energy efficient than the conventional oxo process because it converts renewable resources to isobutyraldehyde in a low-temperature environment using energy efficient separation and purification processes; this was confirmed by preliminary simulation results. Commodity chemicals produced from renewable resources have a lower carbon footprint as well. Additional economic benefits will be realized for feed producers who supply the renewable feed stock.

Applications in Our Nation's Industry

The availability of bio-isobutyraldehyde would allow for the direct replacement of most of the petroleum-derived isobutyraldehyde. If developed successfully, it will be the most straightforward method to convert fossil feedstocks to bio-based feedstocks. The technology platform can easily be extended to other bio-based chemicals and biofuels, including butyraldehyde and isobutanol.

Project Description

The main goal of this research effort was to develop a bio-oxo process that converts renewable resources, such as corn stover, to isobutyraldehyde using metabolically engineered bacteria. By the end of the project, researchers planned to integrate a pilot scale fermentation unit with downstream collection and purification units to demonstrate the feasibility of commercial-scale isobutyraldehyde production. However, in August 2017, Easel Biotechnologies decided the continued development of the Bio-Oxo technology was no longer in line with the future business direction of the company and the decision was made to terminate the project.

Barriers

- Production of significant quantities of isobutyraldehyde for scale-up using selected enzymatic pathway.
- Economically favorable integration of the fermentation process with the separation and purification processes.
- Confirming bio-oxo isobutyraldehyde as a drop-in replacement to the oxo-produced isobutyraldehyde.

Pathways

Researchers selected and optimized a bacterial production strain that can use corn stover feedstock to produce isobutyraldehyde and then further engineered the strain to favor and improve isobutyraldehyde production. Separation and purification methods were developed that are compatible with the fermentation process while taking advantage of the low vapor pressure and boiling point of isobutyraldehyde. Operational conditions were optimized after the integrated system was constructed. A fully integrated pilot scale fermentation and purification unit was not constructed due to the early termination of the project.

Milestones

This three-year project began in December 2014 but was terminated in August 2017 before project completion.

- Develop a fermentation and separation process for the selected strain to produce isobutyraldehyde at 0.3 g/L/hr and titer of 10g/L (Completed).
- Optimize the enzyme strain and pathway and develop an integrated process to produce isobutyraldehyde at 0.5g/L/hr and titer of 30 g/L (Completed).
- Demonstrate the integrated production process at pilot scale by producing isobutyraldehyde at 1.0g/L/hr and titer of 50 g/L (2017).

Accomplishments

- Demonstrated biological production of isobutyraldehyde from corn stover hydrolysate (up to 56 g/L in a 14L fermentor).
- Easel Biotechnologies, LLC was granted a patent for their "Microbial Synthesis of Aldehydes and Corresponding Alcohols" in August 2015.

Technology Transition

Data from the completed runs was used to generate preliminary simulation results indicating that the gas-stripping separation method used in this process could reduce energy use by more than 45% compared to the current isobutyraldehyde chemical synthesis process. Unfortunately the project was ended before the technology could be verified at the pilot scale, a necessary step before partners would likely invest in a demonstration scale plant.

Project Partners

Easel Biotechnologies, LLC
Los Angeles, CA
Principal Investigator: Wendy Higashide
Email: *wendy.higashide@easelbio.com*

For additional information, please contact

Dickson Ozokwelu
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-2561
Email: *Dickson.Ozokwelu@ee.doe.gov*

Project final report available at *www.osti.gov/scitech: OSTI Identifier 1437008*

U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

For more information, visit:
energy.gov/eere/amo

DOE/EE-1679 · October 2018