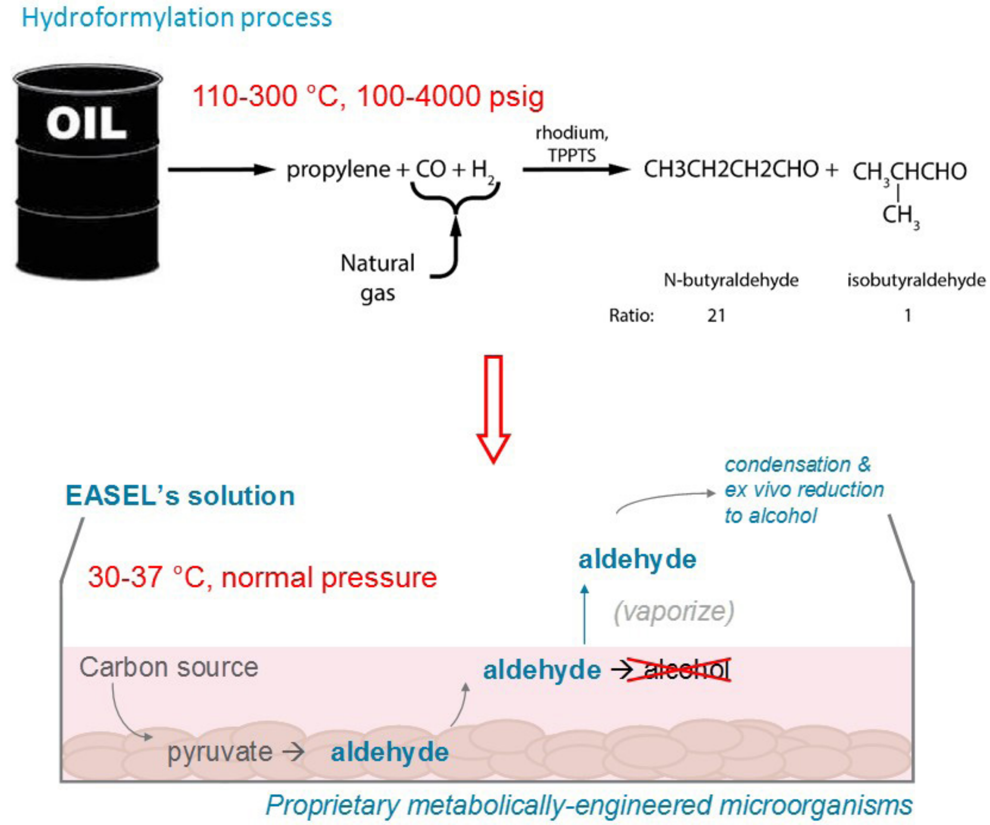
Bio-Oxo Technology

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 propose to develop a more energy efficient bio-oxo process that will take 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 will use innovative, metabolically-engineered bacteria to convert renewable resources to isobutyraldehyde via low-temperature, energy-efficient processes. The proposed 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. *Image courtesy of Easel Biotechnologies.*

Benefits for Our Industry and Our Nation

The proposed 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. Commodity chemicals produced from renewable resources will 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. 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 is to develop a bio-oxo process that will convert renewable resources, such as corn stover, to isobutyraldehyde using metabolically engineered bacteria. By the end of the project, researchers will integrate a pilot scale fermentation unit with downstream collection and purification units to demonstrate the feasibility of commercial-scale isobutyraldehyde production.

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 will select and optimize a bacterial production strain that can use corn stover feedstock to produce isobutyraldehyde and will then further engineer the strain to favor and improve isobutyraldehyde production. Separation and purification methods will be developed that are compatible with the fermentation process while taking advantage of the low vapor pressure and boiling point of isobutyraldehyde. Operational conditions will be optimized after the integrated system is constructed. Finally, a fully integrated pilot scale fermentation and purification unit will be constructed using the final production strain.

Milestones

This three-year project began in December 2014.

- 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 0.6g/L/hr and titer of 30 g/L (2016).
- Demonstrate the integrated production process at pilot scale by producing isobutyraldehyde at 1.0g/L/hr and titer of 50 g/L (2017).

Commercialization

At every stage of the project, industrial processes are being considered to enable commercial scale-up. During the final stage of the project, researchers will develop an integrated pilot scale production process, including the fermentation and downstream purification units, and will conduct approximately 20 fermentation runs. Data from these runs will be used to finalize a techno-economic analysis of the bio-oxo process and will include production cost estimates, a detailed life cycle analysis, and potential greenhouse gas reduction estimates. Researchers are actively seeking a strategic partner, preferably an aldehyde producer, to form a joint venture to construct a demonstration plant once commercial feasibility of the process is confirmed.

Note that in August,2015, Easel Biotechnologies, LLC was granted a patent for their "Microbial Synthesis of Aldehydes and Corresponding Alcohols."

Project Partners

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