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Organic Waste to Syngas to Ethanol

I represent project development for LeMar Industries in Santa Fe Springs, CA, feeding agricultural waste to a unique process for low-capital two-stage pyrolysis-partial oxidation of synthesis gas, which is then converted with very low process energy via acetogenic bacteria, as described in the Atiyeh document, said process technology licensed to Le Mar Industries in April 2017.

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Additional submitted attachment is included below.

From: Hasan Atiyeh
To: Joseph Degenfelder
Date: 10/26/2018

RE: Oklahoma State University (OSU) Syngas Fermentation

Background
The hybrid conversion technology involves the conversion of biomass syngas components (H_2, CO and CO_2) into liquid biofuels and chemicals. Mass transfer limitations, low cell productivity, enzyme inhibition, and the high cost of fermentation medium are major challenges for this conversion route. OSU research team is tackling these challenges through examining cell metabolism and process development of novel microorganisms, reactor design, scale-up and process modeling. This research has enhanced fundamental understanding of syngas fermenting microorganisms, genes, and enzymes responsible for CO and H_2 consumption and selectivity for alcohol production.

OSU syngas fermentation team have developed various tools to facilitate design and control of large-scale bioreactors with increased alcohol productivity and selectivity and gas utilization to make the hybrid conversion process for the production of biofuels economically viable. We developed a novel method to sustain culture activity, gas uptake, and improve selectivity for ethanol production during syngas fermentation. We discovered that the addition of activated carbon in the fermentation medium sustained the acetogen's activity, prolonged the fermentation process, and resulted in a high concentration of ethanol produced. In 2018, my team obtained a U.S. Patent No. US 10,053,711 B2) entitled "Method Improving Producer Gas Fermentation". The patented method resulted in the production of twenty-six times the ethanol concentration compared to the conventional method. The enhanced ethanol production and fermentation stability were attributed to the effect of carbon in altering the mass transfer and presumably in retaining the nutrients to sustain fermentation activity.

My team also developed a patented novel pH control method for ethanol production from syngas (U.S. Patent No. US 10,017,789 B2) in 2018. The gas flow was automatically adjusted by a proportional-integral-derivative process controller to control the pH in the fermentation broth. The development of automatic control of syngas feed rate which maintained constant pH, increased stability, ethanol selectivity and concentration, and doubled the production of ethanol assures commercial potential in the biofuel industry. We also developed a control algorithm to maximize the conversion of syngas to ethanol and productivity based on mass transfer, kinetics, and thermodynamic parameters of the fermentation process. The algorithm provides an effective new tool for process design and control of fermentation, described in U.S. Patent Application Publication No. US 2017/0356012 A1.

Our findings on syngas fermentation and biochemical conversion processes have been published in over 40 peer-reviewed journal publications, two peer-reviewed book chapters, two U.S. Patents, six U.S. Patent Applications, four Provisional Patent Applications, 12 published conference papers, 164 conference oral/poster presentations, 27 invited lectures and, 30 magazine and newspaper articles, videos and instructional material.

Future plans:

OSU's Aspen Plus gasification-syngas fermentation model predicted an annual production of 37 million gallons of ethanol from 1200 tons per day switchgrass (Bioresource Technology, 245, 925-932, 2017). My team's plan is to modify the existing 2017 ASPEN Plus process flow diagram to include a two-stage reactor, include design parameters and perform sensitivity analysis to check effect of various operating parameters on energy conservation, ethanol yield and productivity. Successful completion of this project will result in development of stable and efficient two-stage syngas fermentation for ethanol production. The process is broadly applicable and will support global economic activity in sustainable energy and chemical production. With an industrial partner, there is a great potential that this project will be successful in achieving its objectives with opportunities for technology transfer to the private sector nationally and internationally.