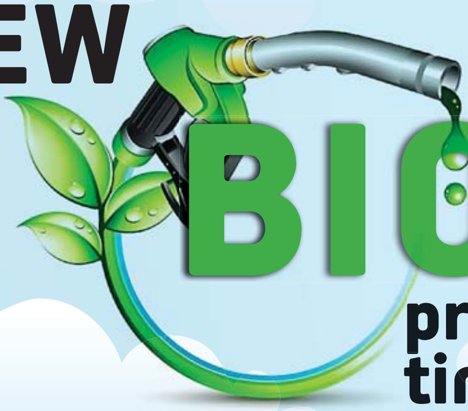
NEW BIOFUEL process produces 20 times more energy



Researchers at Michigan State University (MSU) in the US have developed a new method that uses microbes to produce biofuel and hydrogen while consuming agricultural wastes. *Energy Next* presents a detailed account of the new technology

With an aim to enhance the production of energy from biomass, Gemma Reguera, a Michigan State University microbiologist, has developed bioelectrochemical systems known as microbial electrolysis cells (MECs), which can produce 20 times more energy than existing methods. The results of a new study, published in the journal, *Environmental Science and Technology*, show a novel way to use microbes to produce biofuel and hydrogen, all while consuming agricultural wastes.

MECs use bacteria to break down and ferment agricultural waste into ethanol thereby leading to an increase in the output. Similar microbial fuel cells have been investigated before. Gemma Reguera's fuel cells use corn stover treated by the ammonia fiber expansion process, an advanced pretreatment technology pioneered at MSU. However, maximum energy recoveries from corn stover, a common

feedstock for biofuels, hover around 3.5 per cent. The aim behind this research is to develop decentralised systems that can help process agricultural wastes. These decentralised systems could be customised at small to medium scales to provide an attractive method to recycle the wastes while generating fuel for farms.

Deviating from the practice of focusing on a single microbe capable of converting cellulose to ethanol in a fermenter, the team of researchers led by Gemma Reguera has worked on culturing two bacteria that grow synergistically. In this process, ethanol and hydrogen are the two fuels created, wherein the hydrogen is produced from electricity generated by one of the bacteria.

Bruce Dale, MSU professor of chemical engineering and materials science had earlier worked on developing ammonia fiber expansion (AFEX) process- an already proven method in the field of biofuel production, and is in the process of making it viable on a commercial scale. On the similar lines, Gemma Reguera is busy working on her research to optimise her MECs in order to make them scalable on a commercial basis. She said that the work done by Bruce Dale treating corn stover and other waste biomass with the AFEX process was intriguing to them because it mimicked what fungi do in nature to remove lignin

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and facilitate the hydrolysis of cellulose for symbiotic microorganisms. They then looked for natural organisms that would degrade AFEX pretreated cellulose into ethanol. Her team basically worked on consolidated bioprocessing of AFEX (pretreated corn stover) to ethanol and hydrogen in an MEC.

According to Gemma Reguera, this platform is unique because it employs a second bacterium, which, when added to the mix, removes all the waste fermentation byproducts or

Dr Gemma Reguera,
Associate Professor,
Department of Microbiology and Molecular Genetics,
Michigan State University

non-ethanol materials while generating electricity. The second bacterium, Geobacter sulfurreducens, generates electricity. The electricity, however, isn't harvested as an output. It is used to generate hydrogen in the MEC to increase the energy recovery process even more. When the MEC generates hydrogen, it actually doubles the energy recoveries. In the process, the researchers increased energy recovery to 73 per cent, hence assuring that it has huge potential in making this platform attractive for processing agricultural wastes.

"Despite the energy invested in chemical pretreatment of the corn stover, averaged 35 to 40 per cent energy recovery just from the fermentation process. This is because the fermentative bacterium was carefully selected to degrade and ferment agricultural wastes into ethanol efficiently and to produce byproducts that could be metabolized by the electricity-producing bacterium," said Gemma, an AgBioResearch scientist who co-authored the paper with Allison Spears, MSU graduate student. "By removing the waste products of fermentation, the growth and metabolism of the fermentative bacterium also was stimulated. Basically, each step we take is custom-designed to be optimal," she added.

Led by Dr Gemma Reguera, this team of researchers at Michigan State University worked on developing a new biofuel production process.

'Rural areas in India will benefit from this technology'

Dr Gemma Reguera has developed bioelectrochemical systems known as microbial electrolysis cells, or MECs, using bacteria to breakdown and ferment agricultural waste into ethanol. She speaks to ***Energy Next*** about the process and its prospects

Q What prompted you to take up this study on biofuel?

Our interest was in developing technologies for the processing of agricultural wastes and their conversion into readily usable and storable fuels, there the interest in ethanol and hydrogen. We focused on electrochemical systems to harness energy from both fermentation and microbially-generated electricity, which we could then convert into hydrogen with just a small electrical input.

Q What major hurdles did you have to tackle while doing the research?

There were many challenges along the way because we wanted to mimic the consortia of microorganisms that efficiently degrade lignocellulose in nature, but in a simplified way that would allow us to study the process under controlled conditions and manipulate it for further improvement. Bacteria have evolved for millions of years to degrade lignocellulose in nature. They do so by cooperating with each other effectively, so lignocellulose degraders live together with bacteria that remove the fermentation products and complete the processing of organic matter all the way to CO_2. This is kind of a natural division of labor to be more efficient as a group than as an individual. We hypothesised that we could harness

this efficient and synergistic process through careful selection of two bacteria cooperating with each other. This was the major challenge: going from a highly diverse environmental consortium to only two bacteria working synergistically and effectively.

We used a chemical pretreatment (the AFEX pretreatment developed by our colleague Bruce Dale) to mimic the first steps in lignin solubilisation and lignocellulose destabilisation in nature, which are mainly carried out by fungi. We then screened natural cellulolytic bacterial isolates to identify those that could efficiently degrade the AFEX-corn stover and ferment it into ethanol. Among those, we identified one *Cellulomonas uda* that produced non-ethanol fermentation products that could be converted into electricity by another bacterium, *Geobacter sulfurreducens*, in an electrochemical device. Basically, we used a modified bioreactor equipped with an electrode. C. uda grows using the AFEX-corn stover and produces ethanol. At the same time, it produces the 'food' for G. sulfurreducens, which grows on the electrode while removing the non-ethanol products and converting it into CO_2, protons and electrons (electricity).

Q How much time will it take for this technology to become commercially viable?

We have begun to optimize the platform to process industrial solid loadings and to increase ethanol titers to make ethanol distillation cost-effective. As our platform 'cleans up' all the fermentation byproducts, we are also investigating whether we are in fact reducing the costs associated with ethanol distillation. We are ready to begin scaling up. Our first goal is to adapt standard laboratory and then industrial reactors to function as MECs.

Q Will it be helpful for a country like India where a lot of agricultural waste is being used as raw material for biomass energy?

A: Absolutely, our technology can be used in India to efficiently generate power from biomass. It will definitely benefit any rural areas where decentralised reactors at various scales could recycle the waste and recover energy as fuels for farm equipment and household needs.