THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future

Moving towards 2nd and 3rd Generation Feedstock in the Generation of Hydrogen

RD-20 Meeting, Tokyo

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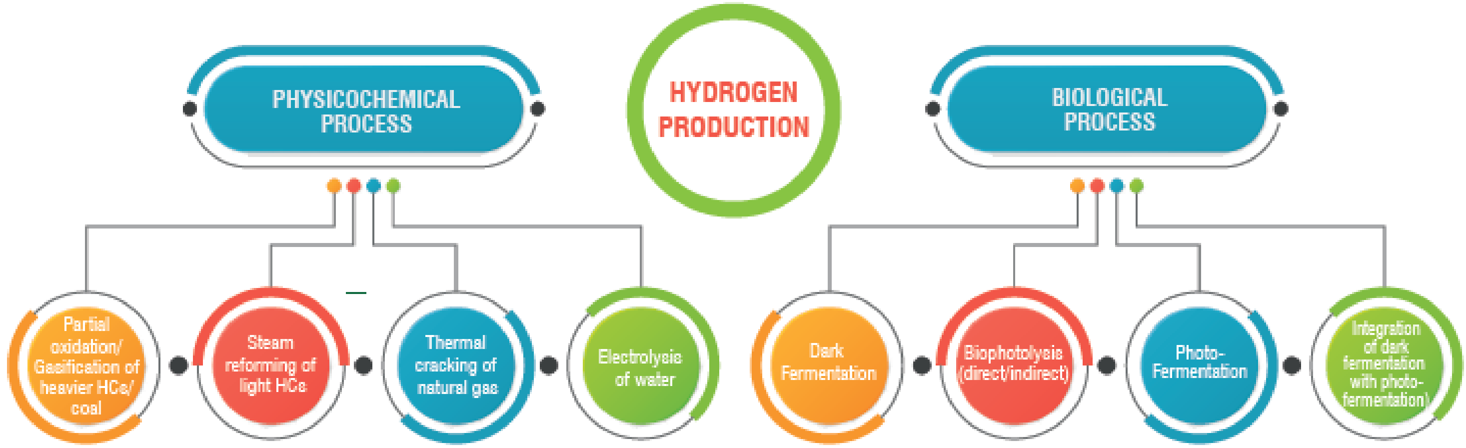
Background

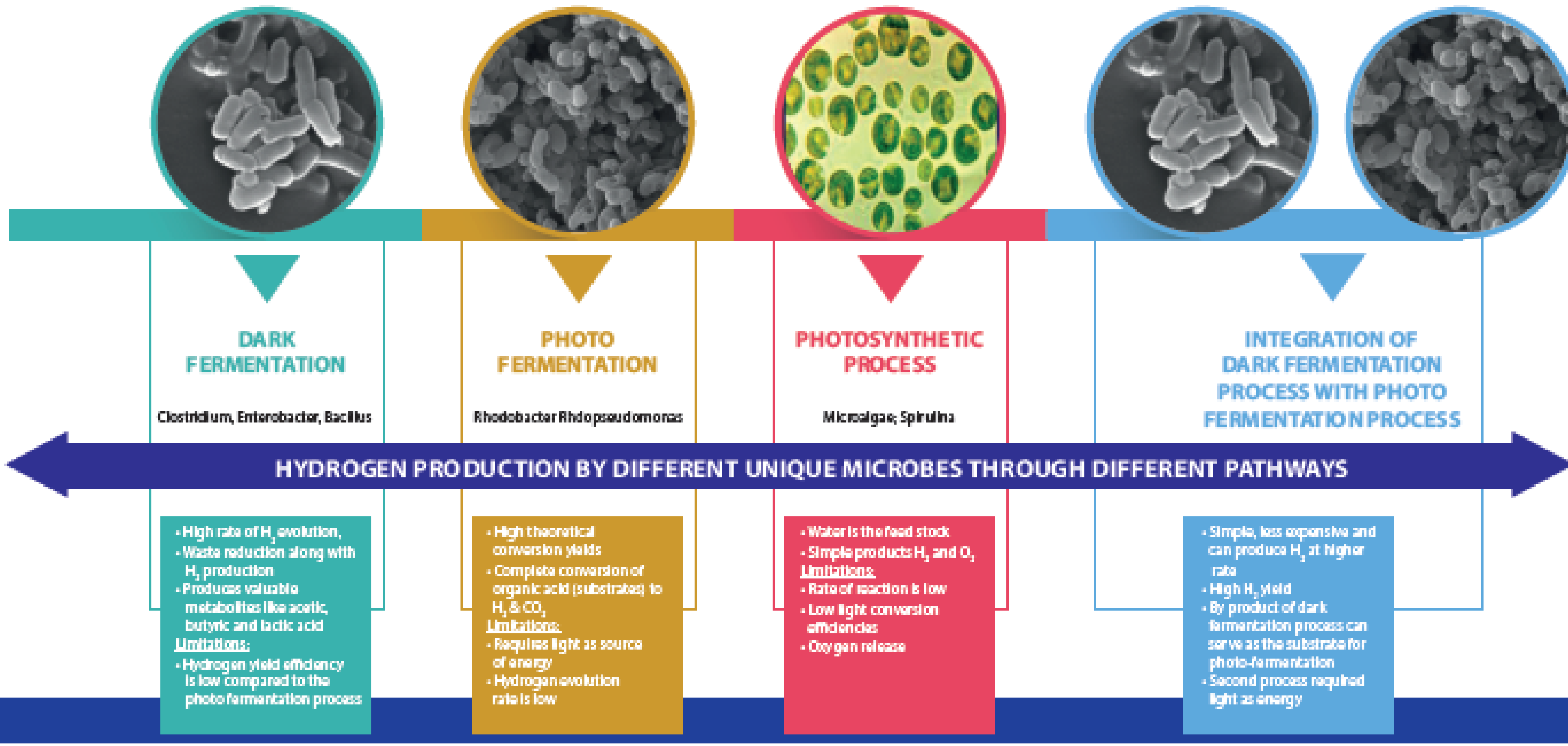
- Among the sustainable energy sources, hydrogen is widely recognized as the most promising fuel because of its clean, recyclable and high efficient nature (122 kJ/g). Current hydrogen production technologies mainly rely on petroleum based resources.
- Around 96% of global hydrogen is produced from fossil fuels, either directly or indirectly (48% from natural gas, 30% from oil, and 18% from coal). Only 4% is produced from water electrolysis.
- Considering the detrimental impact of current hydrogen production technologies, the hydrogen economy has become a global concern now. Globally around 700 billion Nm3 hydrogen produced ,that rely exclusively on fossil fuels.
- This calls for development of hydrogen production in sustainable manner from renewable sources such as; organic waste; non-edible agri-waste biomass
- Hydrogen can be produced biologically from renewable sources through use of specific microbes and algae though various life pathways; dark fermentation process, photo fermentation process, photosynthetic process.
- Dark fermentation process is being widely explored globally for hydrogen production, as this process can make use of organic waste as well as agri-waste biomass as non-edible feedstock for clean hydrogen production



Physico-chemical Processes: • High energy intensive • Emits green house gas

Biological Processes: • Less energy intensive and can be operated at ambient temp. and pressure • Environmental friendly

A Diversity of Biological Pathways



We use agri waste as feedstock

Lignocellulosic biomass as feedstock for hydrogen production: Challenges;

- Lignocellulosic biomass composed of three major components' 'Cellulose, hemi-cellulose and lignin' and the proportion of these vary according to species, tissues and maturity of the plant cell, in the range of '35–50%', '20–35%' and '10–25%', respectively.
- It is essential to convert these complex sugar forms to simple forms In order to use as feedstock for biofuel production. Challenge lie in fractionation of these components and hydrolysis of the complex sugars into simple sugars (glucose, xylose)

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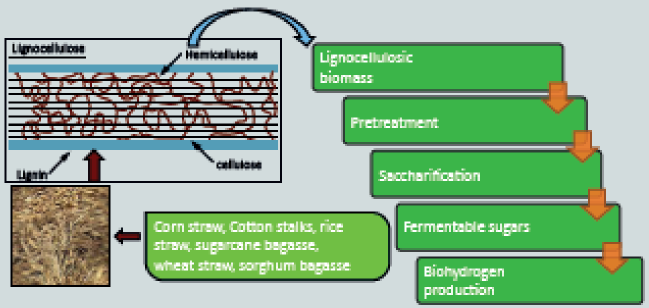
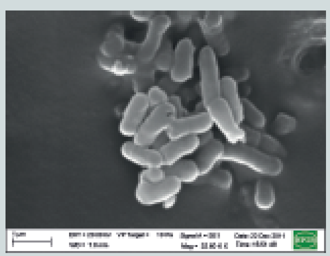


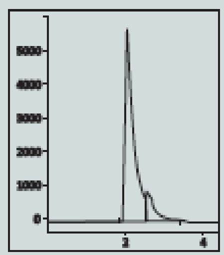
Challenges

- Challenge les in fractionation of these components and hydrolysis of the complex sugars into simple sugars (glucose, xylose)
- For production of 2G hydrogen from these lignocellulosic biomass, it is essential to explore for microbes capable of utilizing glucose and xylose to produce hydrogen

HYDROGEN PRODUCTION FROM C5 SUGAR BY *ENTEROBACTER CLOACAE* THROUGH DARK FERMENTATION ROUTE



Scanning Electron Micrograph of Enterobacter cloacae DT-1 strain



Qualitative detection of hydrogen produced through dark fermentation process by Enterobacter cloacae

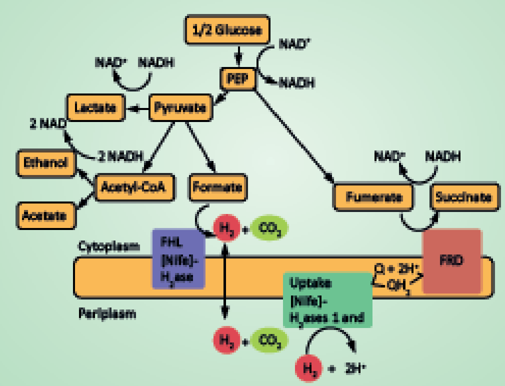
Hydrogen yield efficiency *Enterobacter cloacae* DT-1 strain is –

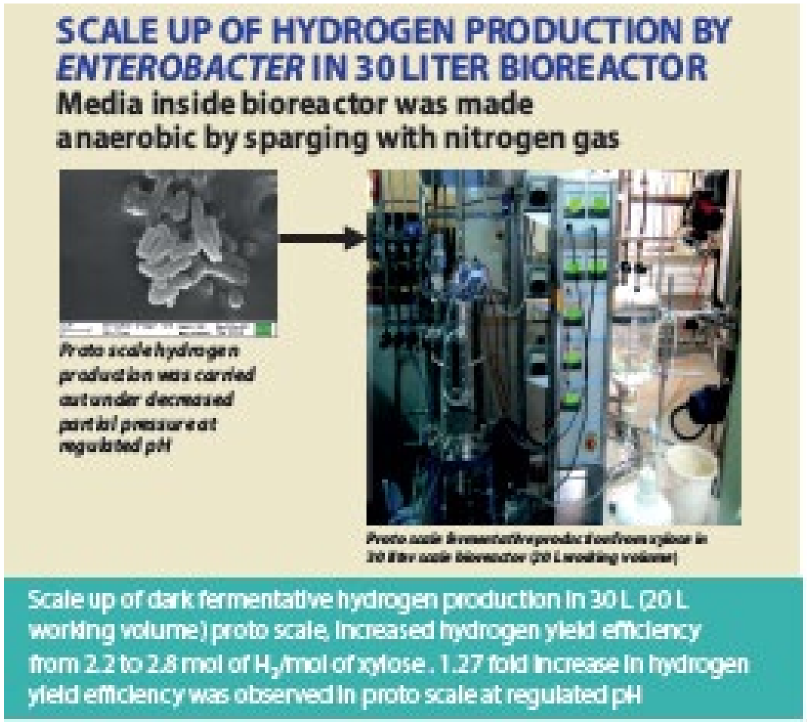
2.2 mol of H_2/ 1 mol of xylose and

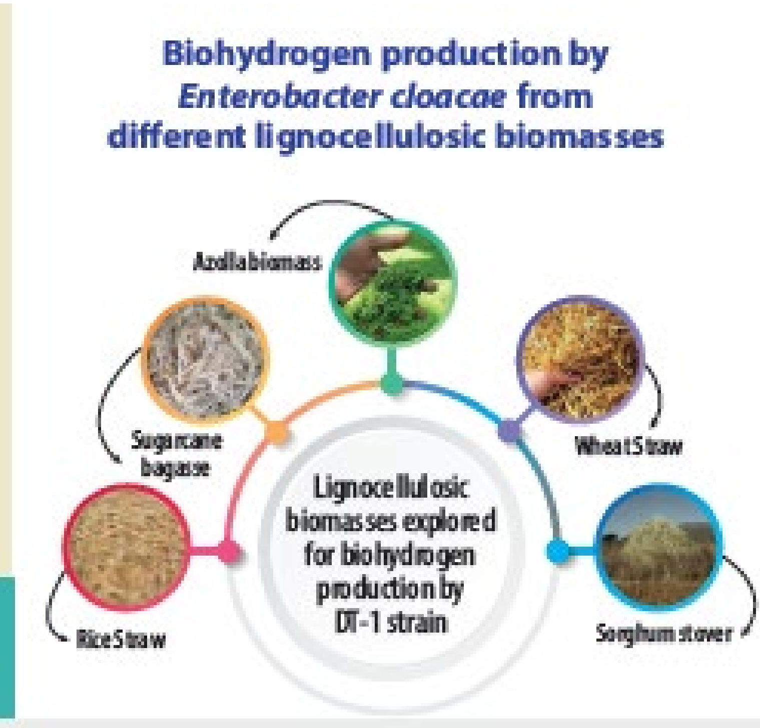
-1.4 mol of H_2/ 1 mol of glucose (In laboratory scale)

(* Maximum hydrogen yield efficiency through dark fermentation route is 3.3 mol of H_2/ 1 mol of xyolse and 2 mol of H_2/mol of glucose)

HYDROGEN PRODUCTION PATHWAY IN ENTERIC BACTERIA

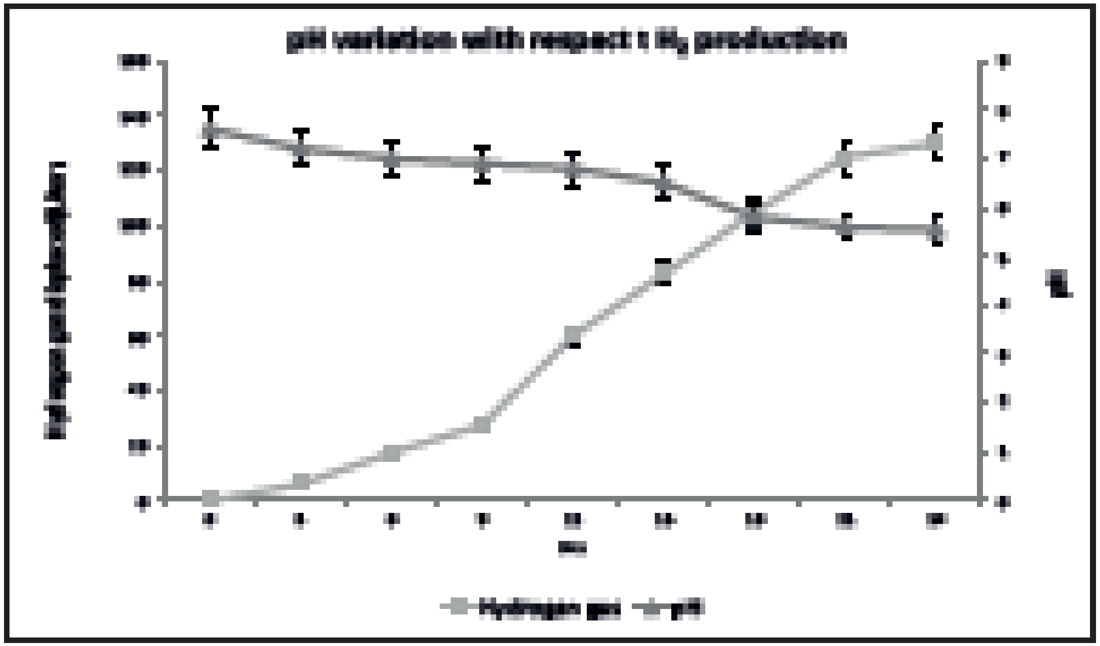



SCALE UP OF HYDROGEN PRODUCTION BY ENTEROBACTER IN 30 LITER BIOREACTOR
Media inside bioreactor was made anaerobic by sparging with nitrogen gas
Proto scale hydrogen production was carried out under decreased partial pressure at regulated pH
Proto scale fermentative production from xylose in 30 liter scale bioreactor (20 L working volume)
Scale up of dark fermentative hydrogen production in 30 L (20 L working volume) proto scale, increased hydrogen yield efficiency from 2.2 to 2.8 mol of H2/mol of xylose. 1.27 fold increase in hydrogen yield efficiency was observed in proto scale at regulated pH


Biohydrogen production by Enterobacter cloacae from different lignocellulosic biomasses
Azolla biomass
Sugarcane bagasse
Wheat Straw
Rice Straw
Sorghum stover
Lignocellulosic biomasses explored for biohydrogen production by DT-1 strain


System sparged with Nitrogen gas to maintain anaerobic condition
System was sparged with nitrogen
2nd generation H2 production from acid treated rice straw (provided by DBT-IOC center) in 13 liter bioreactor
2nd generation H2 production from acid treated wheat straw (provided by DBT-IOC center) in 30 liter bioreactor
2nd generation H2 production from acid treated sugarcane bagasse in 150 liter bioreactor
2nd generation H2 production from enzymatic saccharified sugarcane bagasse (provided by DBT-ICT Center, Mumbai and India Glycol Limited, Kashipur) in 200 liter bioreactor
Biogas generated in the bioreactors was pass through gas flow meter for volumetric quantification. Qualitative H2 detection was done by online gas analyzer.

Process is attractive for Scale-Up



Biogas (H_2 + CO_2) production profile of Enterobacter cloacae from sugarcane bagasse biomass sugar (provided by India Glycol Limited, Kashipur) in 200l the bioreactor (Batch fermentation). Biogas was composed of 55–60 % H_2. Hydrogen production efficiency was 2.7 mol per mole of reducing sugar.

Conclusion

- This process has significant potential for scale up of second generation clean hydrogen production from non-edible agri-waste residue biomass, in large scale.
- Currently cost is one of the major challenge. To make the overall process cost competitive, it is essential to integrate thsi process with biomethae production by using organic acid rich spent effluent of this process, as feedstock.
- Maturaton of this technology will pave the way for commercialization of this process.




Thank You