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OVERCOMING LIMITATIONS TOWARDS COMMERCIALIZATION OF BIOFUELS

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HP Green Research and Development Centre, Bangalore
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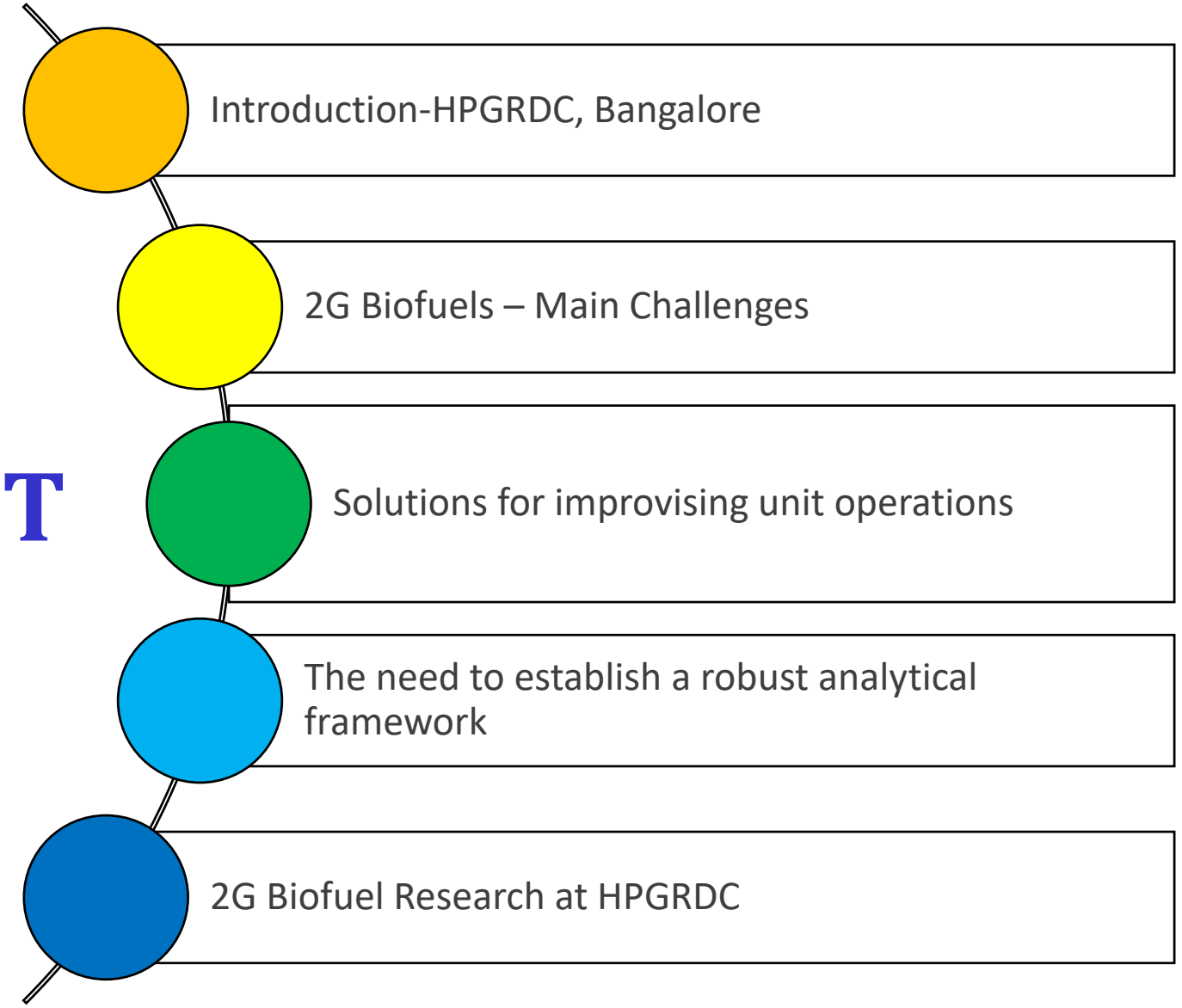
CONTENT


Introduction-HPGRDC, Bangalore
2G Biofuels – Main Challenges
Solutions for improvising unit operations
The need to establish a robust analytical framework
2G Biofuel Research at HPGRDC

HINDUSTAN PETROLEUM CORPORATION LIMITED

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हिन्दुस्तान पेट्रोलियम कॉर्पोरेशन लिमिटेड
Hindustan Petroleum Corporation Limited

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ABOUT US | PRODUCTS & SERVICES | PRESS & MEDIA | INVESTORS | CSR & ENVIRONMENT | CAREERS

- HPCL is a Maharatna company.

- HPCL owns & operates 2 major refineries-Mumbai (West Coast) of 7.5 MMTPA and in Visakhapatnam (East Coast) of 8.3 MMTPA capacity producing a wide variety of petroleum fuels & specialties.

Delivering

Happiness...

- HPCL in collaboration with M/s Mittal Energy Investments Pte. Ltd. operates 9 MMTPA capacity refinery at Bathinda with 49% equity and also holds an equity of about 16.95% in the 15 MMTPA Mangalore Refinery and Petrochemicals Ltd. (MRPL).

- HPCL has the second largest share of product pipelines in India with a pipeline network of more than 3370 km for transportation of petroleum products and a vast marketing network consisting of 21 Zonal offices in major cities and 128 Regional Offices.

HPCL R&D: THEN AND NOW

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2012
Recognized by DSIR

2019

HINDUSTAN PETROLEUM GREEN R&D CENTER

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HP GREEN R&D CENTRE
Bengaluru

HPCL R&D – TECHNOLOGIES & PRODUCTS

HPCL R&D Centre has made major technical accomplishments in terms of developing & commercializing novel technologies and products in refineries which led to significant cost advantages and efficiency improvements in HPCL.

26	85	13	14
International Publications	Patents Filed	Patents Granted (India, US, Europe, Japan)	Products / Technologies

HP GREEN R&D CENTRE, BENGALURU

2G BIOFUEL TECHNOLOGY

IDENTIFYING THE MAIN CHALLENGES

2G BIOFUEL TECHNOLOGIES: MAIN CHALLENGES

The challenges facing widespread biofuels use can be broadly divided into three areas

Feedstock aggregation

- Sustainable feedstock availability
- Collection, transport and logistics

Feedstock conversion

- Multi step complex processes
- High CAPEX OPEX

Biofuel distribution

- Existing 1 G distribution models can be utilized

2G ETHANOL: THE PROCESS

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FEEDSTOCK

RICE STRAW

WHEAT STRAW

SUGARCANE BAGASSE

Collection, Densification, Transportation & Storage

PRE-PROCESSING

- DRYING
- METAL REMOVAL
- STONE REMOVAL
- SIZE REDUCTION

PROCESSING

THERMO-CHEMICAL PROCESS

- PRE-TREATMENT

BIOPROCESS

- ENZYMATIC HYDROLYSIS
- FERMENTATION

PRODUCT SEPARATION

PHYSICAL PROCESS

- DISTILLATION
- MEMBRANE SEPERATION

ETHANOL (Liquid fuel)

FEEDSTOCK PREPARATION (SIZE REDUCTION)

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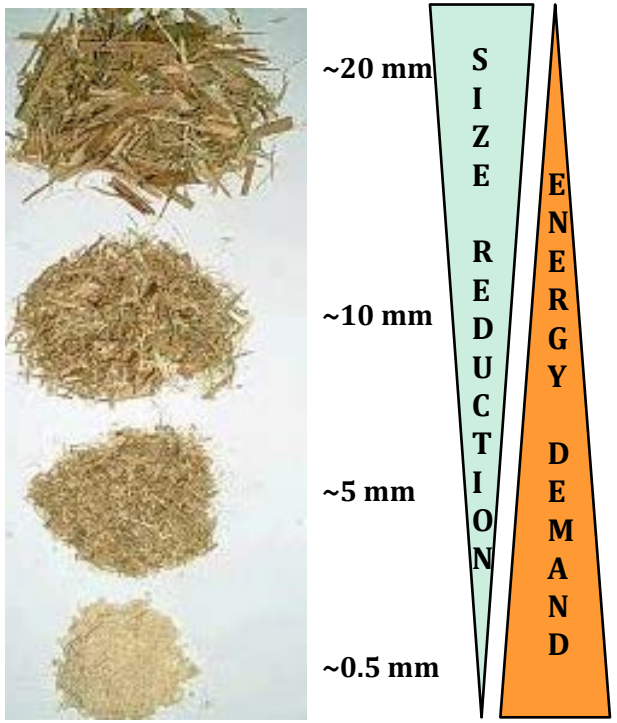
- Biomass size reduction is achieved by a combination of chipping, grinding, and /or milling.
- Final particle size of materials: ~10–30 mm after chipping, ~0.2–2 mm after grinding or milling
- Ball mills, vibratory mills, hammer mills, knife mills, two roll mills, colloid mills, attrition mills, or extruders can be used



MAJOR CHALLENGES

- Energy intensive process
- No right equipment available
- Experience with feedstock sizing is limited (certain feedstock such as cotton stalk can present problems due to presence of lint fibres)

SOLVING THE BIOMASS CONVERSION CONUNDRUM

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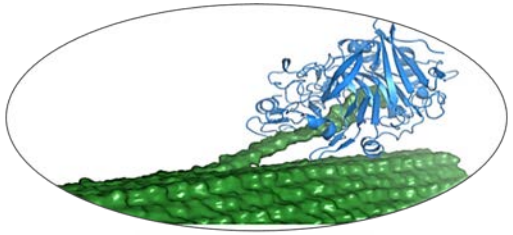
BIOMASS PRE-PROCESSING

BIOMASS PRE-TREATMENT



ENZYMATIC HYDROLYSIS

Biomass Size Reduction	Energy Inputs	Pretreatment severity	Cellulose recovery	Inhibitor Formation	Biochemical yields
LARGE	LOW	HIGH	LOW	HIGH	LOW
SMALL	HIGH	LOW	HIGH	HIGH	LOW
OPTIMUM (?)	**LOW**	LOW/HIGH (?)	**HIGH**	**LOW**	**HIGH**

- A deeper understanding of the biomass conversion conundrum will lead to solutions for overcoming the problems related to biomass sizing.
- All unit operations are being inter-dependant, it is necessary to realize that any change in one unit operation will lead to changes in subsequent processes.

BIOMASS PRETREATMENT

- After size reduction, the biomass is subjected to deconstruction by thermochemical processes

BIOMASS PRETREATMENT METHODS

Lignocellulosic biomass

PHYSICAL
- Mechanical extrusion
- Milling
- Microwave
- Ultrasound
- Pyrolysis
- Pulsed electric field

CHEMICAL
- Dilute Acid
- Dilute Alkali
- Organosolv
- Ozonolysis
- Ionic liquids
- Deep eutectic solvents
- Natural deep eutectic solvents

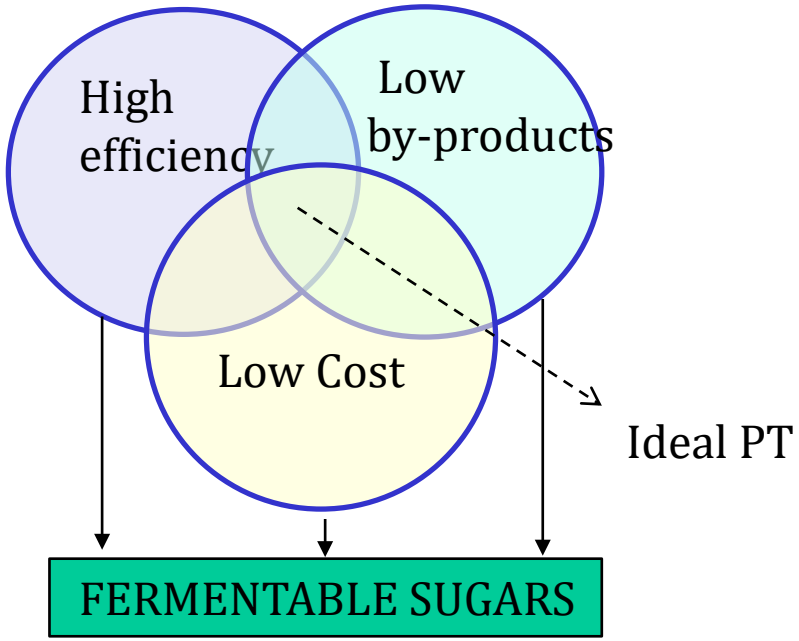
PHYSICOCHEMICAL
- Steam explosion
- Liquid hot water
- SPORL
- Ammonia based
- CO2 explosion
- Oxidative pretreatment
- Wet oxidation

BIOLOGICAL
- Fungi Bacteria
- Archaeal

BIOMASS PRETREATMENT

A SUITABLE AND AN EFFICIENT PRETREATMENT SHOULD

- Result in minimal inhibitor formation
- Maximize cellulose recovery
- Require minimal chemicals and water that should preferably be recyclable
- be feedstock agnostic
- Have lowest energy requirement
- Have low CAPEX requirements



- The pretreatment process developed / selected should have the above-mentioned attributes.
- Pretreatment severity may vary depending upon feedstock composition.
- Ideally, a feedstock agnostic process is desired; however, a particular process may also be slightly altered to suit the feedstock

ENZYME PRODUCTION AND BIOMASS HYDROLYSIS

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Enzyme production

- Enzymes are expensive.
- The cost of enzyme production is very high due to low fungal productivities

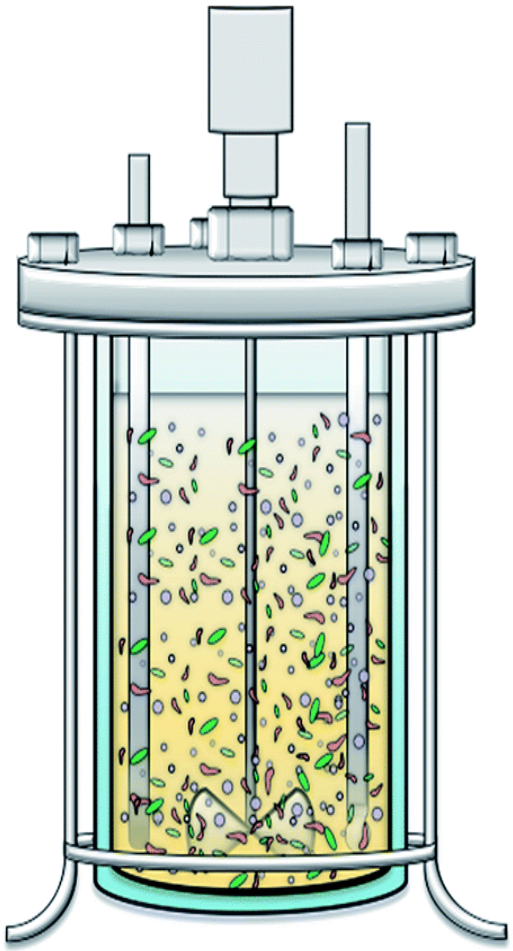
Biomass Hydrolysis

- Time consuming
- Requirement of higher enzyme dosages for biomass hydrolysis

- Developing efficient microbial hosts for higher enzyme production
- Reducing the cost of enzyme production by process optimization
- Improving the amenability of pretreated celluloses during pretreatment

MAJOR CHALLENGES

- Conversion of C5 sugars along with C6 sugars into ethanol will improve ethanol yield
- Inhibitors in hydrolysates can reduce ethanol fermentation efficiencies



- Developing a highly inhibitor tolerant, C5 converting, ethanol producing strain and evaluating its performance in hydrolysate fermentations subsequently is necessary

IMPORTANT LEARNINGS DURING SCALE-UP

Problems that are encountered at larger scales (pilot) may not be envisaged at the laboratory scale

Biomass sizing	**Cleaning/washing**	**Pre-treatment**
Biomass losses due to dust formation	Stone/soil/metal removal, water re-use for subsequent washing	Chemical addition and soaking
Enzymatic hydrolysis	**Fermentation**	**Biomass handling & hardware problems**
Insufficient mass transfer due to high solids loading	*Lactobacillus* contamination	Biomass plugging, equipment corrosion

- Some unit operations s.a biomass sizing and washing, lab scale experimentation differs from pilot scale operations.
- Steep learning curve for process development at the pilot scale (minimum 100 -500 kg)
- Based on existing information, it is prudent to do optimization experimentation at the pilot scale (minimum 100 -500 kg)

THE NEED TO ESTABLISH A ROBUST ANALYTICAL FRAMEWORK

ESTABLISHING THE ANALYTICAL FRAMEWORK

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BIOMASS/ FEEDSTOCK

- Preparation of Samples for Compositional Analysis NREL/TP-510-42620
- Structural Carbohydrates and Lignin in Biomass NREL/TP-510-42618
- Ash (Inorganic) in Biomass NREL/TP-510-42622
- Protein (Nitrogen) NREL/TP-510-42625

SIZE REDUCED BIOMASS

- Preparation of Samples for Compositional Analysis NREL/TP-510-42620
- Structural Carbohydrates and Lignin in Biomass NREL/TP-510-42618
- Ash (Inorganic) in Biomass NREL/TP-510-42622
- Extractives NREL/TP-510-42619
- Total solids NREL/TP-510-42621

PRETREATED SOLIDS

- Preparation of Samples for Compositional Analysis NREL/TP-510-42620
- Structural Carbohydrates and Lignin in Biomass NREL/TP-510-42618
- Sugars, Byproducts, and Degradation Products in Liquid Fraction Process Samples NREL/TP-510-42623
- Total Dissolved solids NREL/TP-510-42621

PRETREATED HYDROLYSATES

SACCHARIFICATION

- Measurement of Cellulase activities NREL/TP-510-42628

  IUPAC Pure & App. Chem., 59 (2): 257—268, 1987.
- Hydrolysability NREL/TP-510-42629 NREL/TP-5100-63351

THE NEED TO ESTABLISH ANALYTICAL FRAMEWORK

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Despite the existence of standard analytical procedures, these are not being uniformly followed all over India.

The reasons for not following the procedures could be : inadequate understanding, improper training, lack of laboratory infrastructure, erroneous data interpretation.

By not following the single standard set of procedures, it has become very difficult to compare results from different labs w.r.t biocatalyst and process efficiencies.

Therefore, evaluation followed by accurate validation of different 2G processes has become difficult.

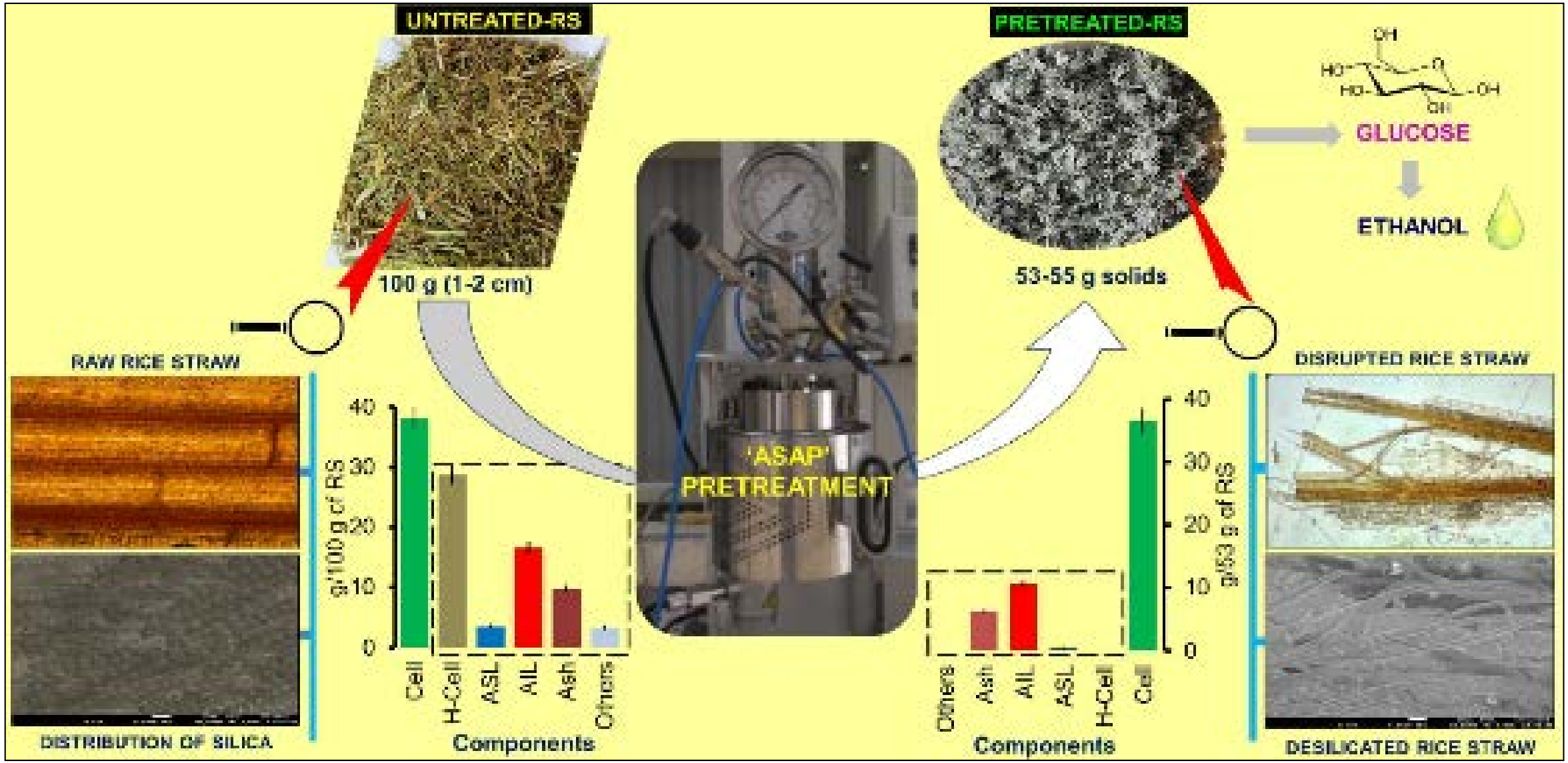
To overcome this, all laboratories to follow standard procedures.

Establishing/Identifying a nodal agency to evaluate/validate all catalysts/ processes

Training programs/workshops to be organized by the nodal agency to other laboratories

2G BIOFUEL DEVELOPMENT AT HPGRDC

BIOMASS PRETREATMENT: HP - ASAP



SCREENING FOR CELLULASE PRODUCING FUNGI

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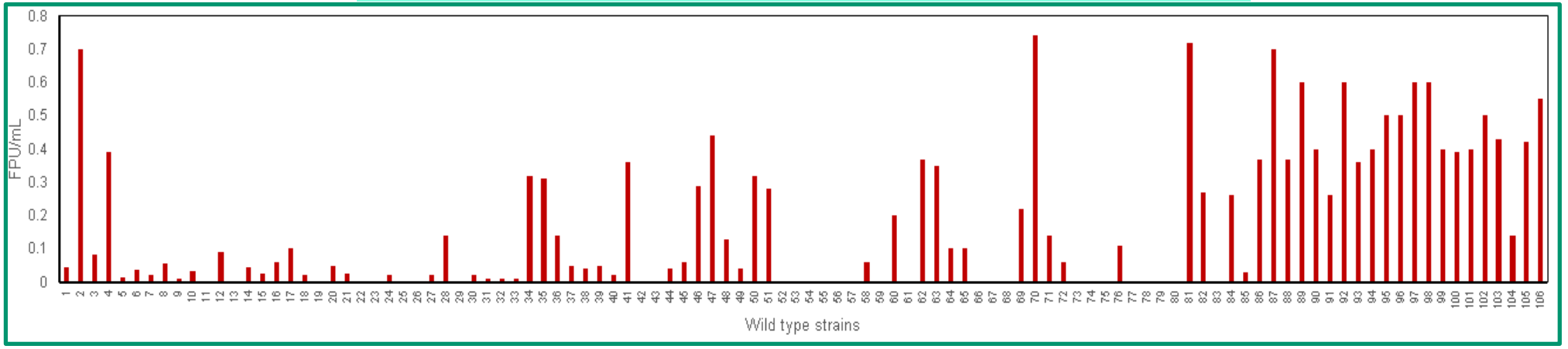
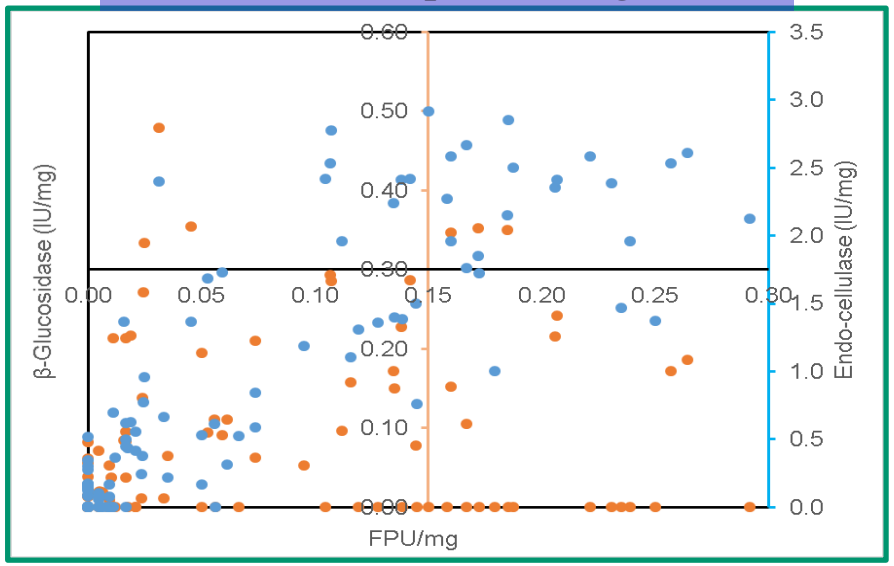
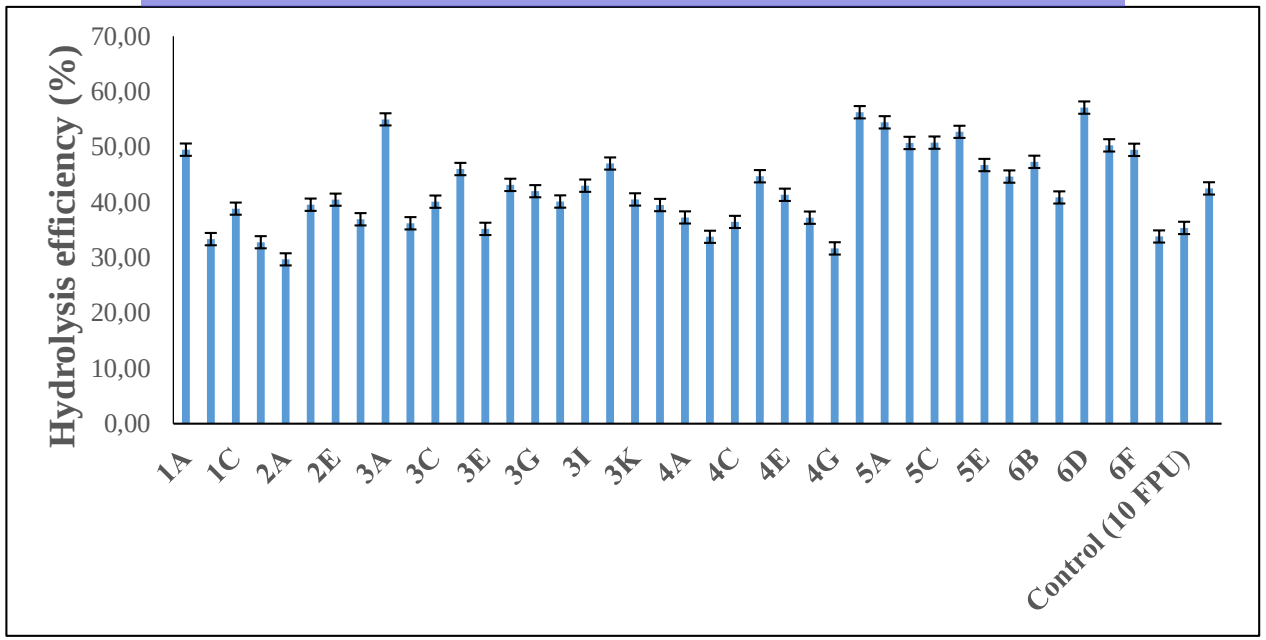
Total cellulase activities observed in wild-type fungal isolates



Selection of best performing strains



Screening for strains producing accessory enzymes



STRAIN DEVELOPMENT FOR IN – HOUSE ENZYME

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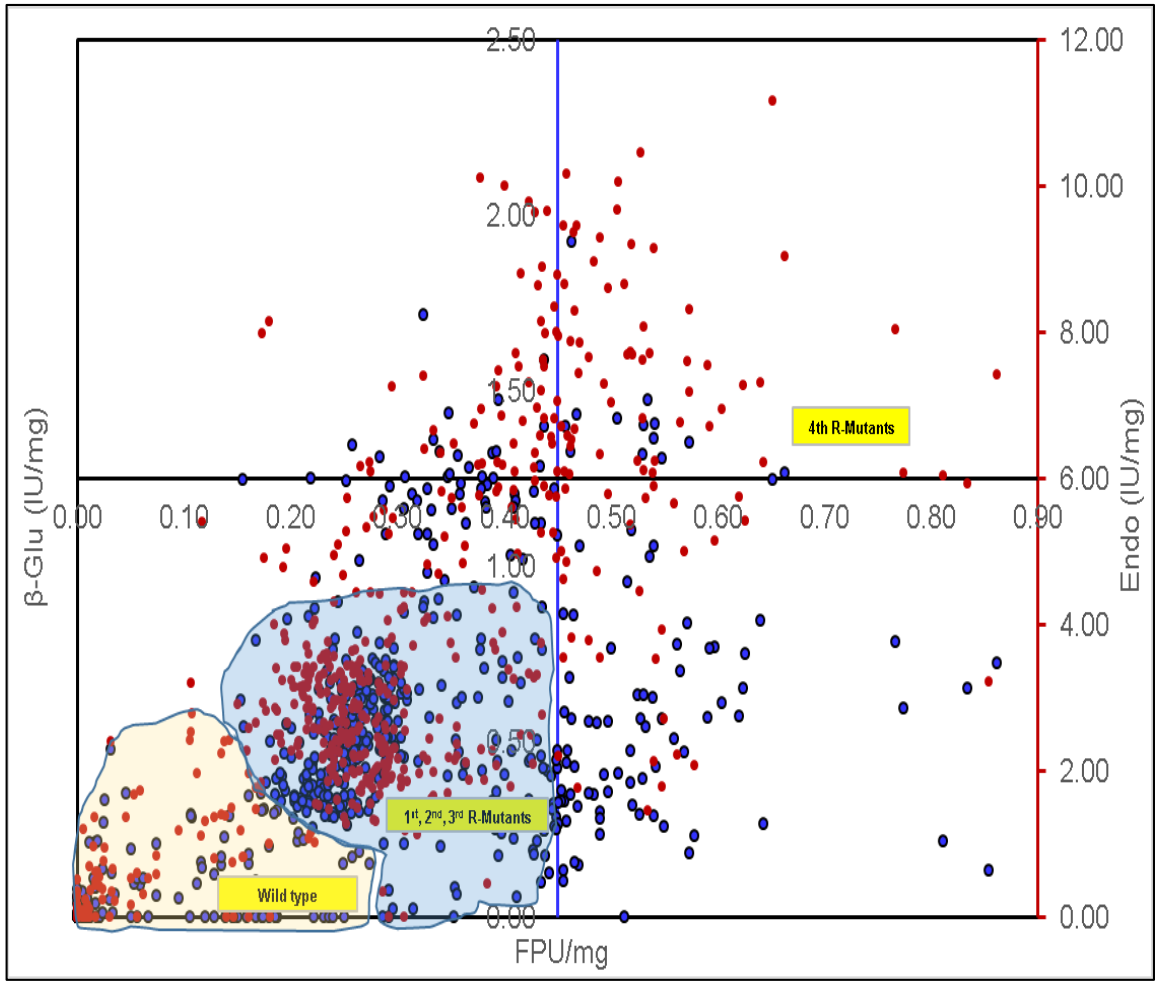
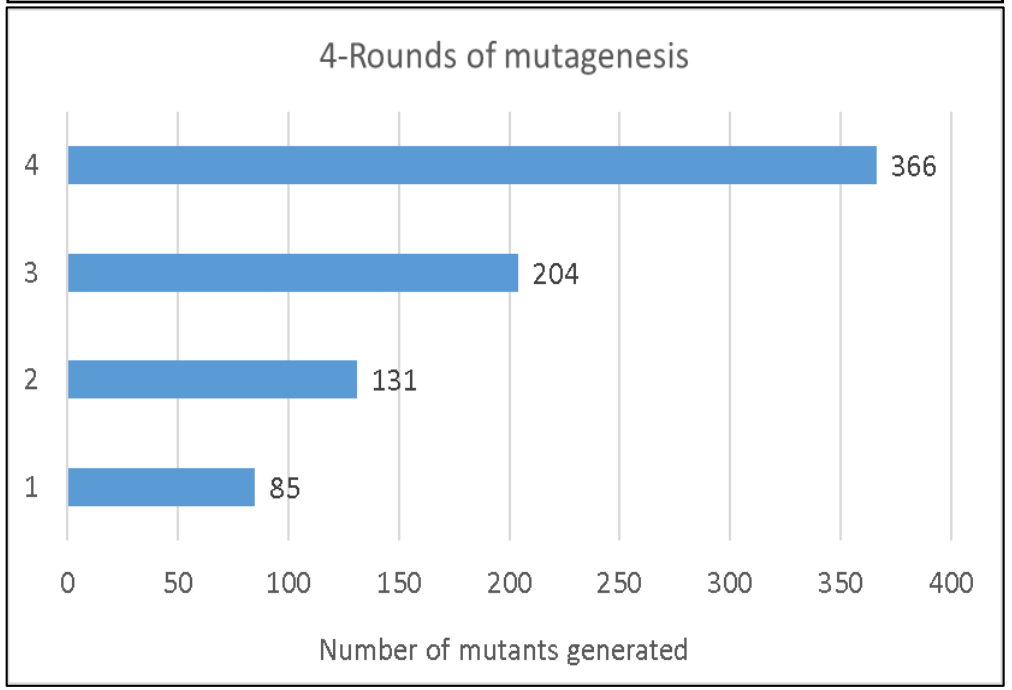


Mutagenesis

Total no. of mutants generated till now: 786

Screening completed for 720 mutants



IN SUMMARY

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- 2G biofuel technologies are highly integrated processes requiring optimization of individual unit operations.
- 2G commercialization is an interdisciplinary activity requiring the inputs and participation by scientists and engineers.
- Learnings from pilot /demonstration scale operations for longer periods will help to improve process efficiencies.
- Adherence to standard analytical procedures is important to establish operational credibility.

THANK YOU

FOR YOUR KIND ATTENTION !