An Innovative and Novel Approach for 2G Ethanol Production Utilizing Lignocellulosic Feedstocks

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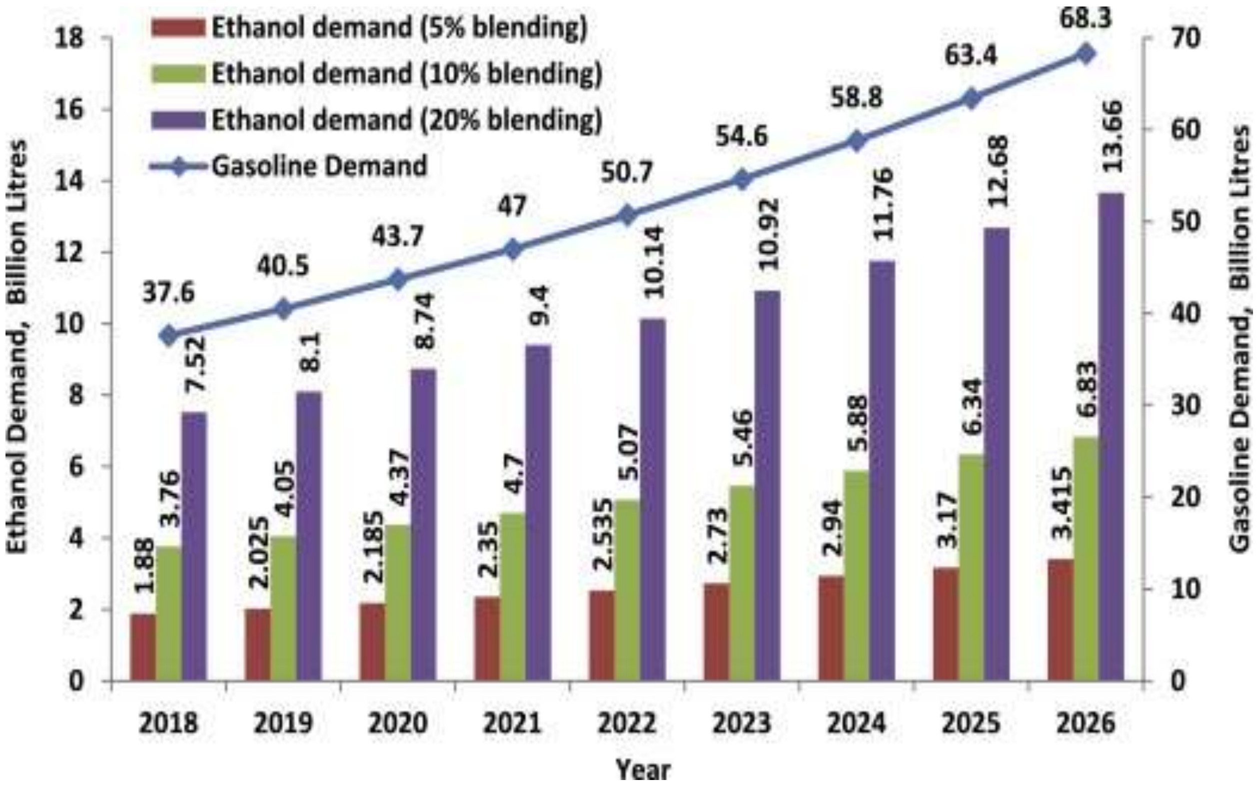
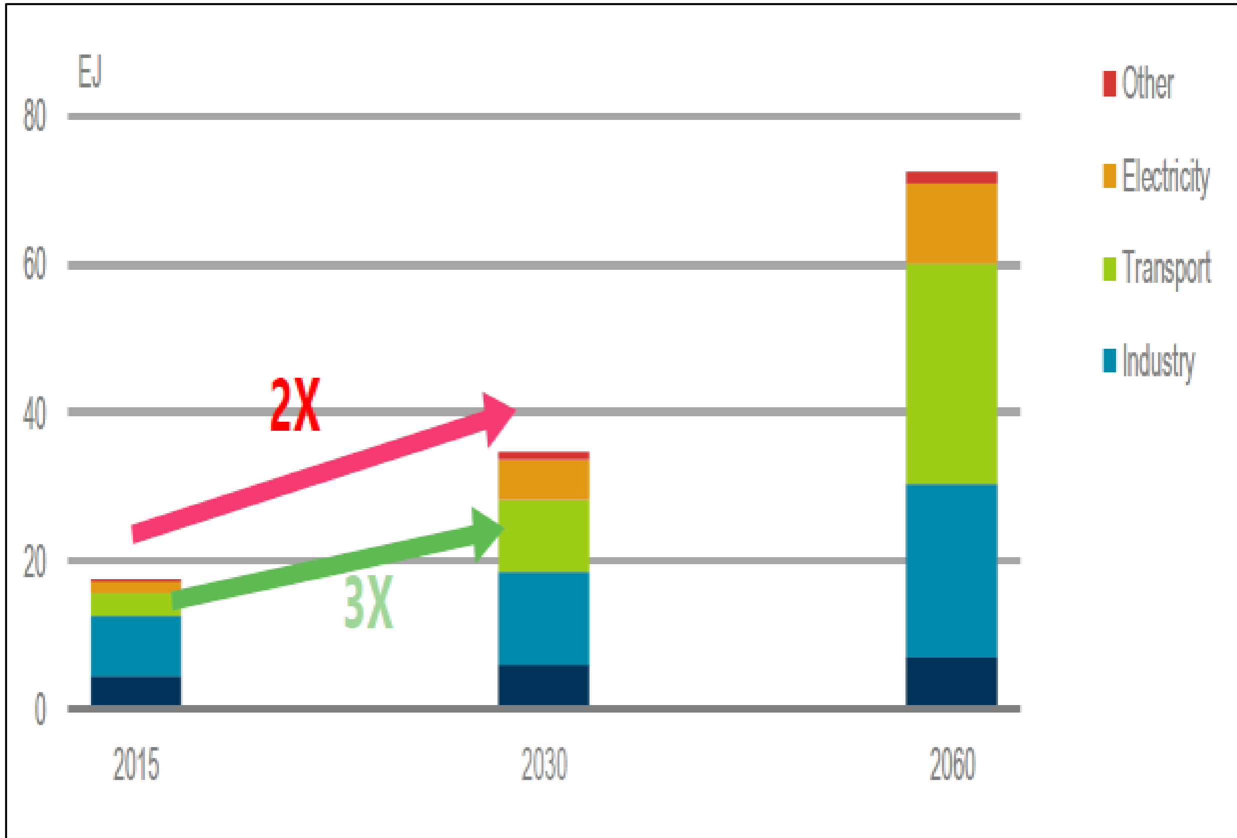
Professor, Agricultural and Food Engineering Department & PK Sinha Centre for Bioenergy and Renewables
Indian Institute of Technology Kharagpur
India

Bioethanol Scenario

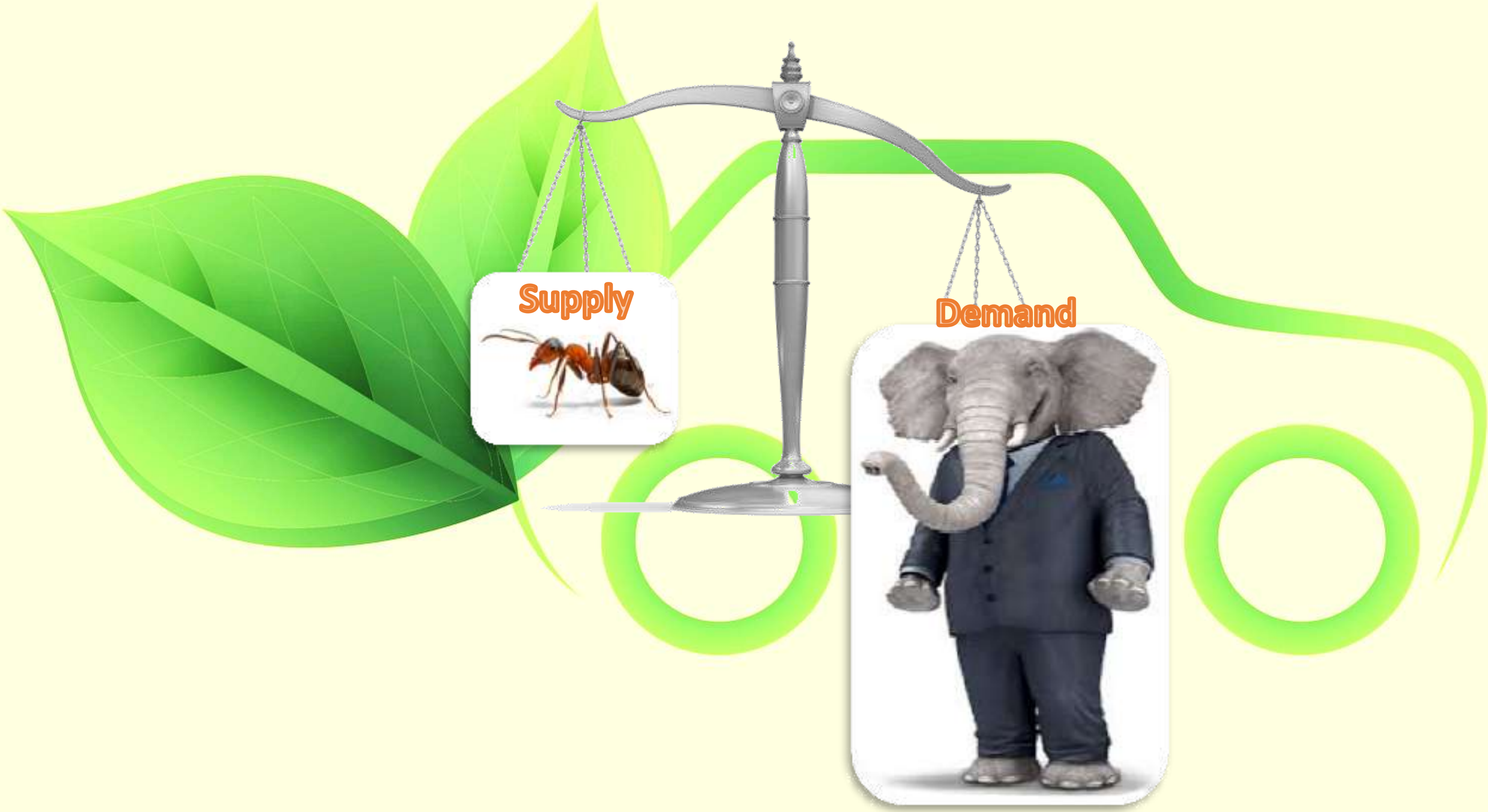


Future demand of gasoline fuel and ethanol for blending ([Sakthivel](#) et al., 2018)

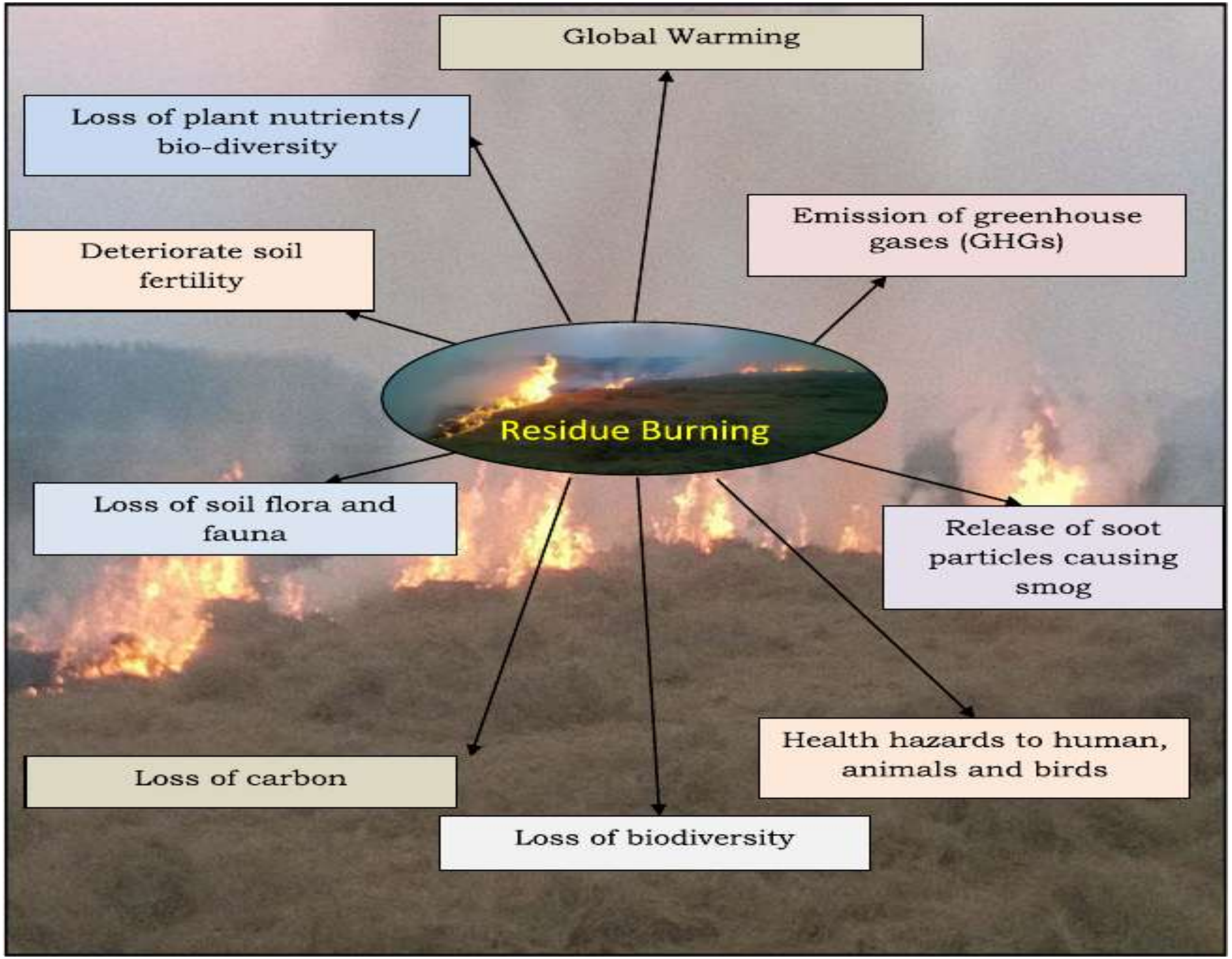
Bioenergy in final energy consumption needs to double by 2030, and biofuels in transport treble. Advanced biofuels will need a massive scale up (IEA, 2017)

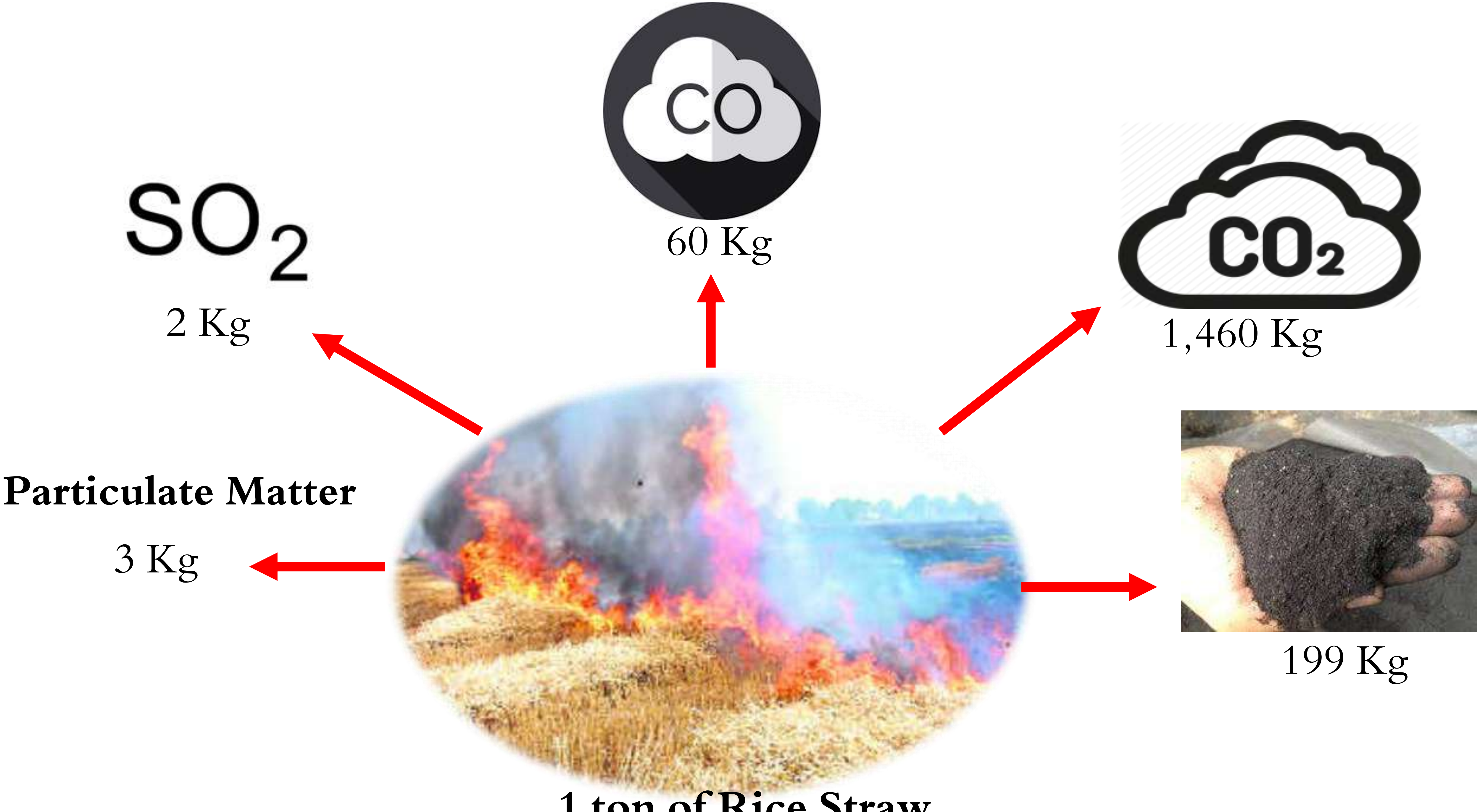


Imbalance in supply and demand of Ethanol



Impact of agro–residue on environment



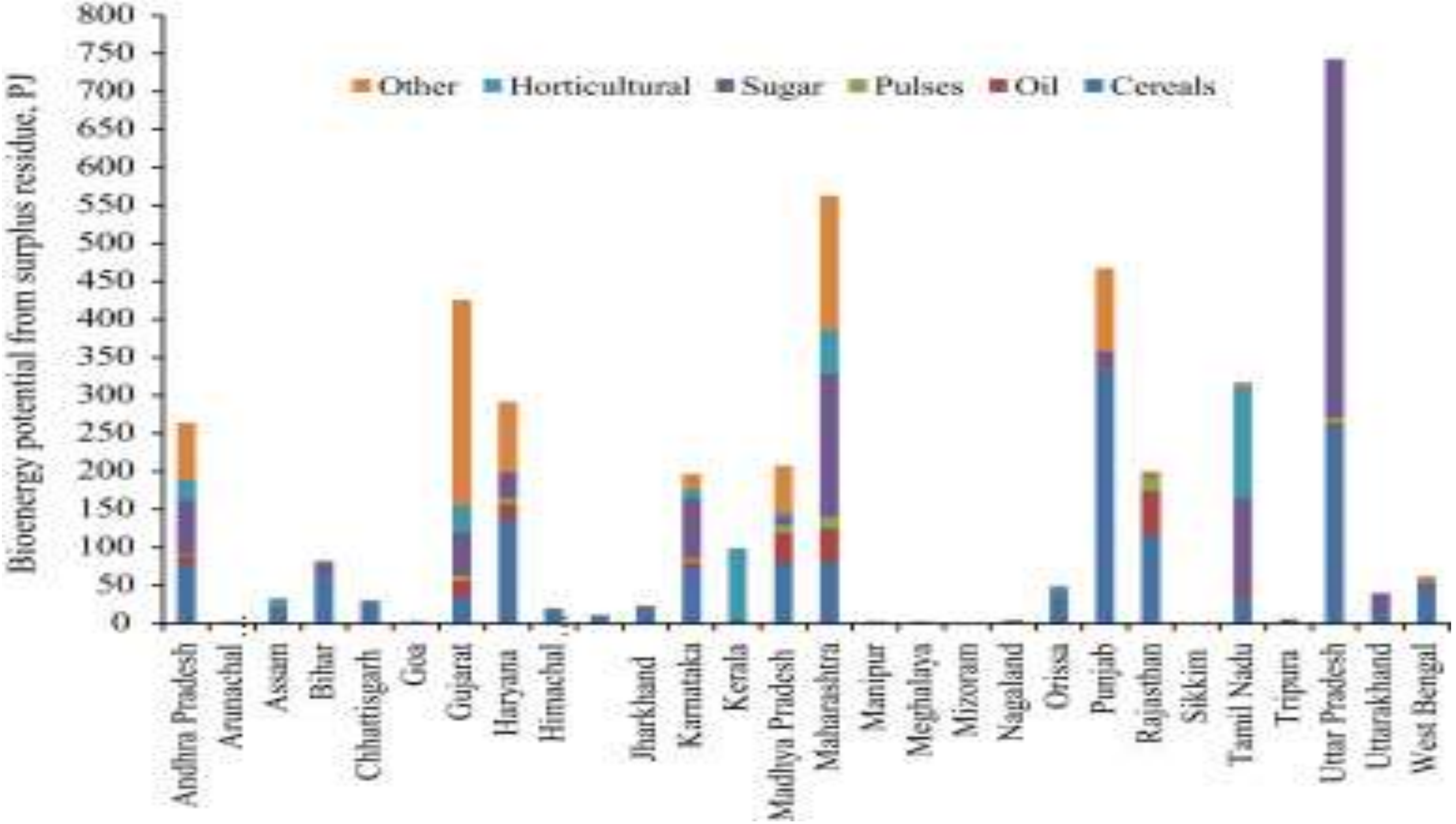


Ministry of New and Renewable Energy (MNRE), 2017


PK Sinha Center for BioEnergy
IIT Kharagpur
India's First Integrated Bioenergy Center

USP of the developed Technology

- Enzyme based delignification and saccharification
- No use of chemicals/physico-chemical processes
- Reaction takes place at mild environmental conditions
- Water requirement is less compared to the other methods
- Eco-friendly and green technology



State wise crop residue bioenergy potential in India (Hiloidhari et al., 2014)

Lignocellulosics Selected for Study at IIT Kharagpur for Bioethanol Production


Ricinus communis


Lantana camara


Kans Grass


Bambusa bambos


Rice straw


Sugarcane Top/Baggase

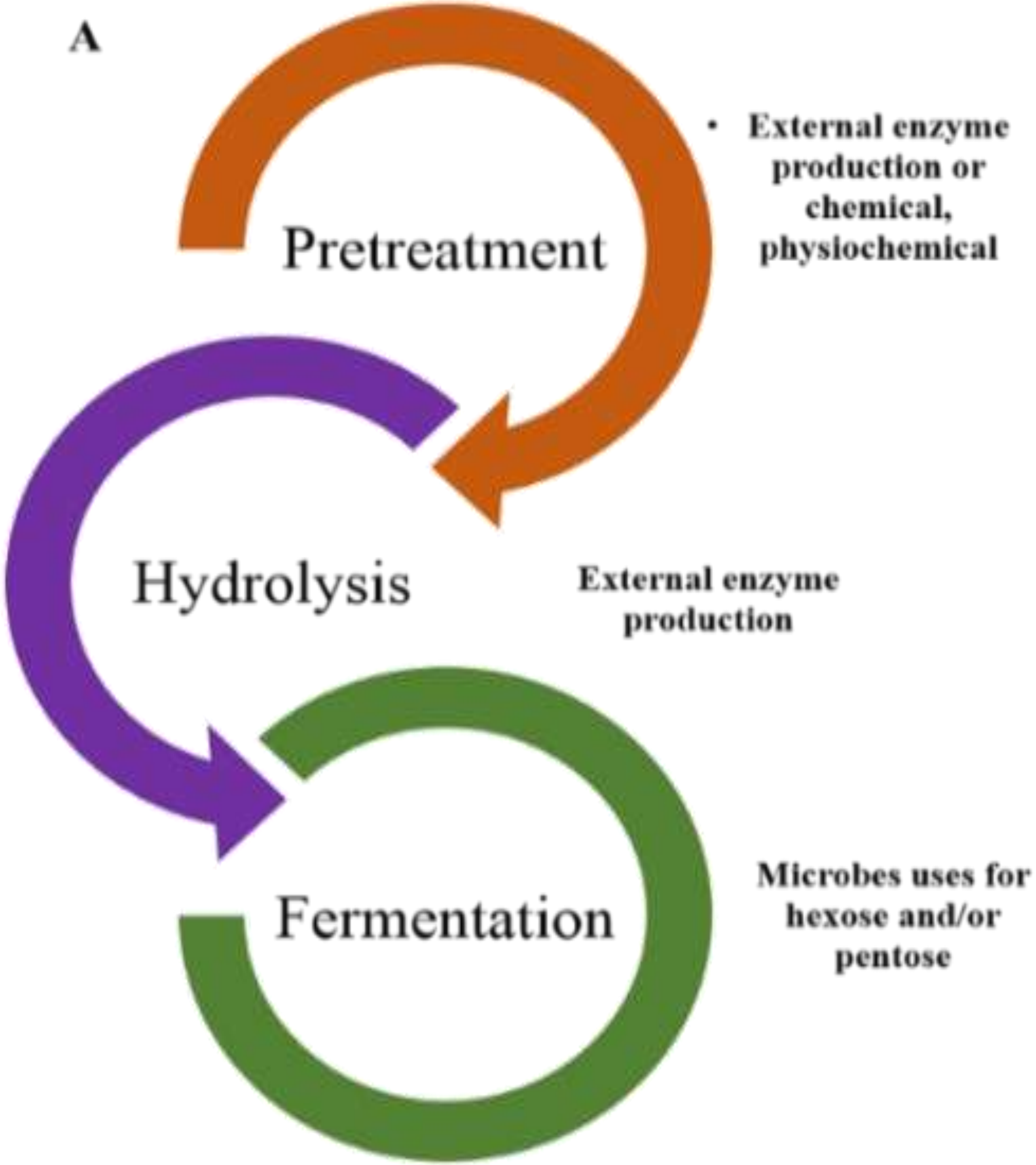

Pineapple leaf waste


Wheat straw


Banana plant


Sweet Sorghum

Steps involved in Sugarcane Baggase/tops for ethanol production



Major Strength of IIT Kharagpur's Technology on INDUSTRIAL ENZYME PRODUCTION that includes:

- In situ Enzyme Production
- Enzymes production Technology
- Robust Enzymes

&

- Technology on Enzymatic Process Development for 2G Ethnaol Production

LACCASE

Yellow laccase

Lentinus squarrosulus

Blue laccase

Pleurotus sp.

White laccase

Myrothecium verrucaria

yellow laccases catalyze reactions using non-phenolic substrates without mediators

Catalyze phenolics, and lignin with the presence of mediator in reaction mixture

Contains one copper, two zinc, and one iron atom instead of 4 and 3 copper atoms in blue and yellow laccase

RSC Advances

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Cite this: RSC Adv., 2016, 6, 61301

Enzyme mediated biomass pretreatment and hydrolysis: a biotechnological venture towards bioethanol production†

Rajiv Chandra Rajak[a] and Rintu Banerjee*[b]

Journal of Environmental Management 217 (2018) 700–709

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Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

ELSEVIER

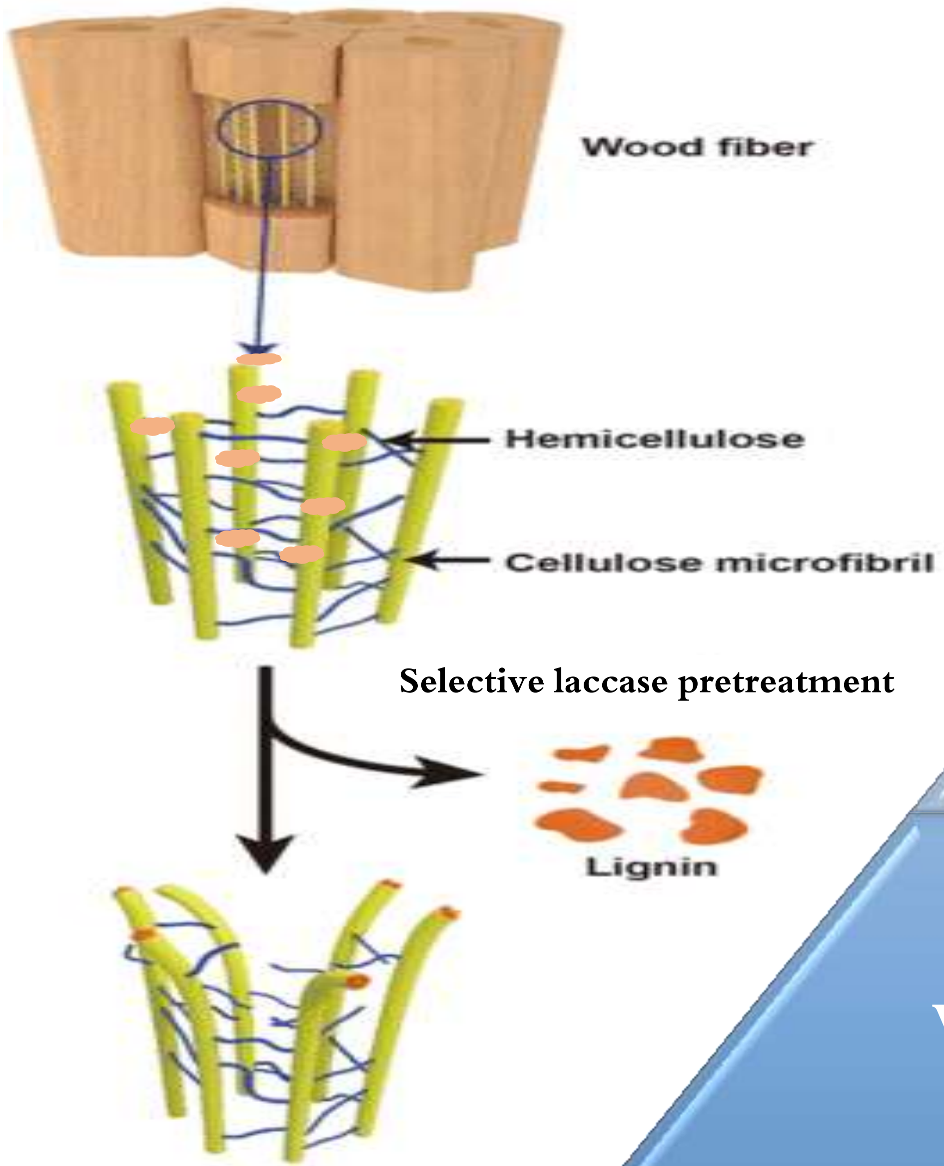
Research article

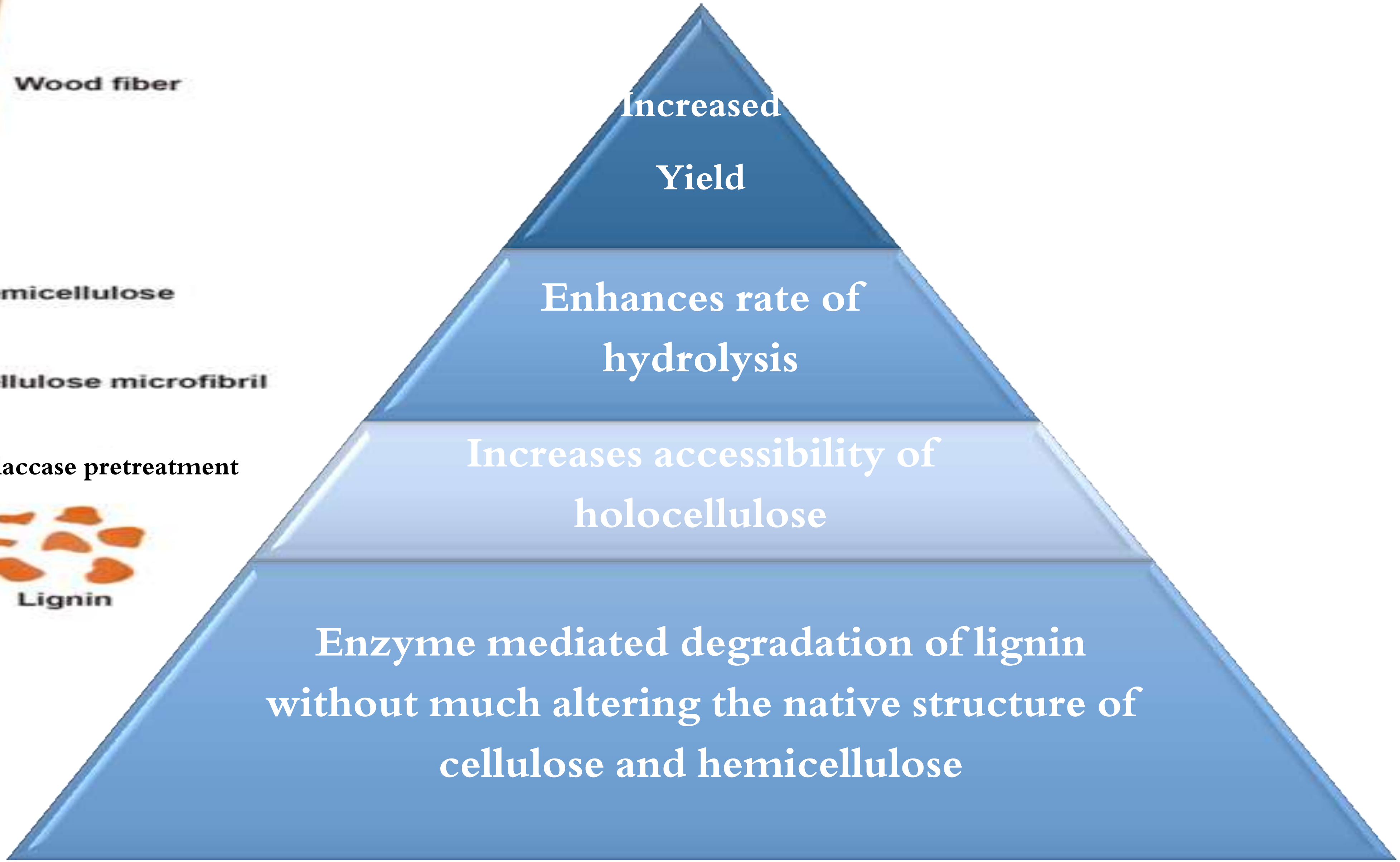
A green and sustainable approach on statistical optimization of laccase mediated delignification of sugarcane tops for enhanced saccharification

Knawang Chhunji Sherpa [c], Makarand Madhao Ghangrekar [b], Rintu Banerjee [a,*]

[a] Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, 721302, India
[b] Department of Civil Engineering, Indian Institute of Technology, Kharagpur, 721302, India
[c] Advanced Technology Development Centre, Indian Institute of Technology, Kharagpur, 721302, India

Advantages of Enzymatic Delignification





Established biomass pretreatment technology with different substrates

Blue laccase

Substrates: *L. camara, R. communis, S. spontaneum, B. bambos, S. Officinarum* tops, *A. comosus* leaf waste, Lignocellulosics Mixture
Optimum conditions: 35–40 °C, **6–8 h**, 15–25% Solid loading, 6–7 pH, 300–500 IU/mL laccase titre, **75–86% delignification %**
Ref: Gujjala *et al.*, 2016; Mukhopadhyay *et al.*, 2011; Rajak and Banerjee, 2015; Kulia *et al.*, 2011; Avanthi and Banerjee, 2016.


Bioresource Technology
Volume 212, July 2016, Pages 47-54
Kinetic modelling of laccase mediated delignification of *Lantana camara*
Lohit K.S. Gujjala, Tapas K. Bandyopadhyay, Rintu Banerjee
https://doi.org/10.1016/j.biortech.2016.04.006


Bioresource Technology
Volume 245, Part A, December 2017, Pages 530-539
Partially consolidated bioprocessing of mixed lignocellulosic feedstocks for ethanol production
Althuri, Avanthi, Gujjala, Lohit Kumar Srinivas, Rintu Banerjee
https://doi.org/10.1016/j.biortech.2017.08.140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An eco-friendly process integration for second generation bioethanol production from laccase delignified Kans grass
Rajiv Chandra Rajak, Rintu Banerjee
https://doi.org/10.1016/j.enconman.2017.11.060


Industrial Crops and Products
Volume 92, 15 December 2016, Pages 174-185
A strategic laccase mediated lignin degradation of lignocellulosic feedstocks for ethanol production
Athuri Avanthi, Rintu Banerjee
https://doi.org/10.1016/j.indcrop.2016.08.009

Yellow laccase

Substrates: *L. camara, R. communis, S. spontaneum, B. bambos, S. Officinarum* tops, *A. comosus* leaf waste, Lignocellulosics Mixture
Optimum conditions: 35–40 °C, **4–6 h**, 15–25% Solid loading, 5–7 pH, 400–800 IU/mL laccase titre, **65–87% delignification %**
Ref: Mukhopadhyay *et al.*, 2011; Rajak and Banerjee, 2016.


Journal of Cleaner Production
Volume 149, 15 April 2017, Pages 387-395
A cleaner and eco-friendly bioprocess for enhancing reducing sugar production from pineapple leaf waste
Rintu Banerjee, Anjani Devi Chintagunta, Subhabrata Ray
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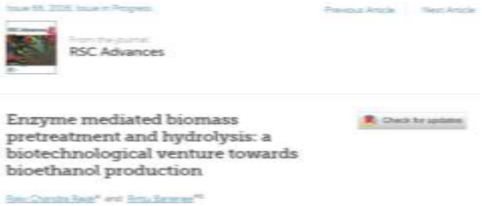

RSC Advances
Enzyme mediated biomass pretreatment and hydrolysis: a biotechnological venture towards bioethanol production

- After rigours research work it has been concluded that laccase although is an efficient enzyme which play a significant role in delignifying the lignocellulosics that initiate the ethanol production process but the major macromolecules being holocellulolytic in nature, will not function properly without efficient saccharifying enzymes

- Thus efficient **Cellulolytic enzymes** have been found to be a prerequisite for ethanol production

A newly isolated strain secreting maximum amount of cellulase that is not only hyperactive but also efficiently saccharifying the entire delignified biomass to reducing sugars within a short span of time

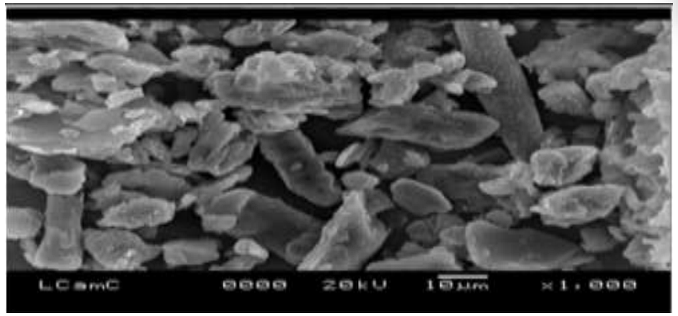
This enzyme is also found to be compatible with laccase and the hydrolysable intermediates produce during delignification

The product cost of cellulase has been **drastically dropped down** so that the overall production cost for ethanol generation has been successfully reduced

Biochemical Characterization

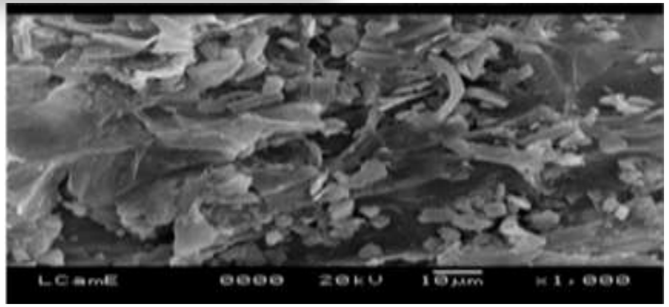
Biochemical composition	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Rice straw	33	16	14
Lantana camara	47.25	16.4	17.26
Ricinus communis	42.00	18.02	19.88
Bambusa bambos	45.00	17.00	19.20
Sugarcane Tops	33.00	22.76	13.45
Kans Grass	38.70	29.00	17.46
Pineapple leaf waste	42.00	25.00	13.00
Mixture	43.02	24	14.57

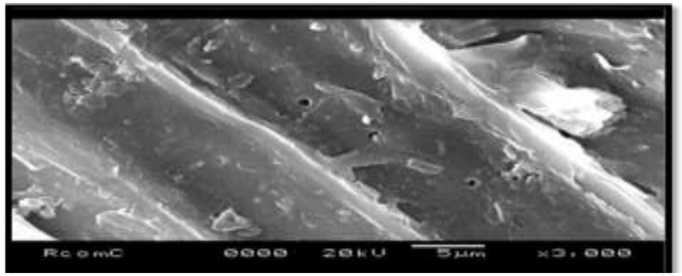
SEM analysis



Control
Lantana camara

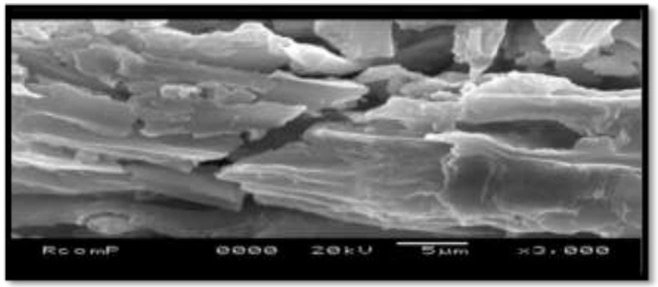
Pretreated
Lantana camara

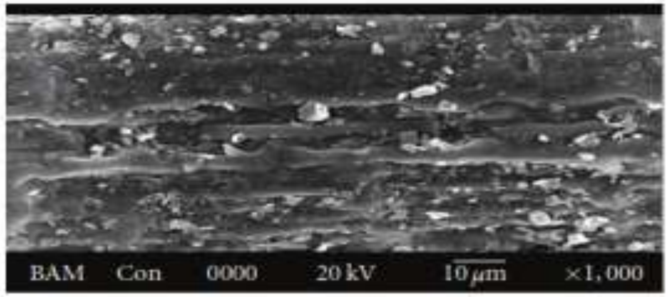




Control
Ricinus communis

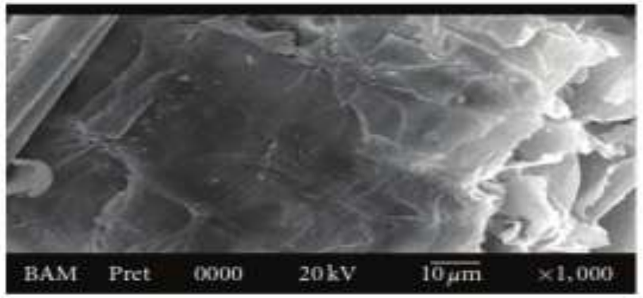
Pretreated
Ricinus communis

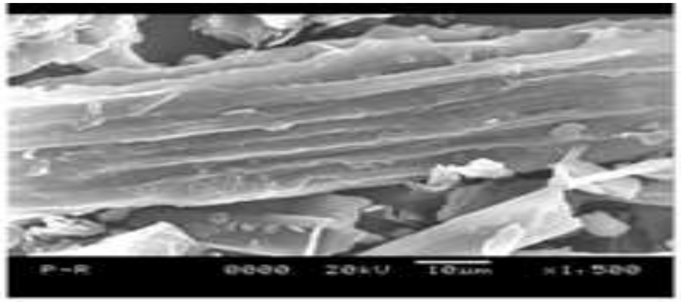




Control
Bambusa Bambos

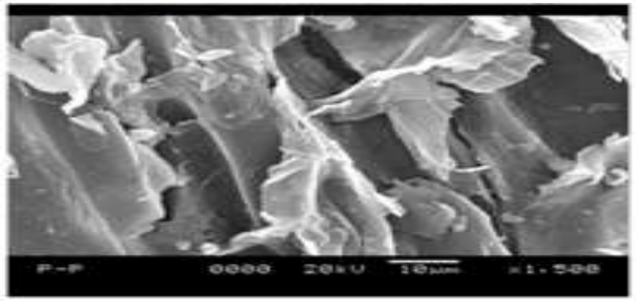
Pretreated
Bambusa Bambos



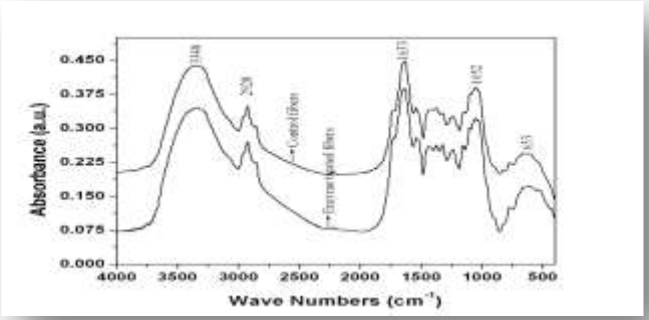


Control
Pineapple leaf

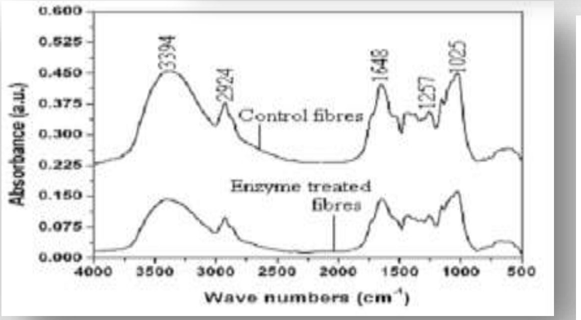
Pretreated
Pineapple leaf



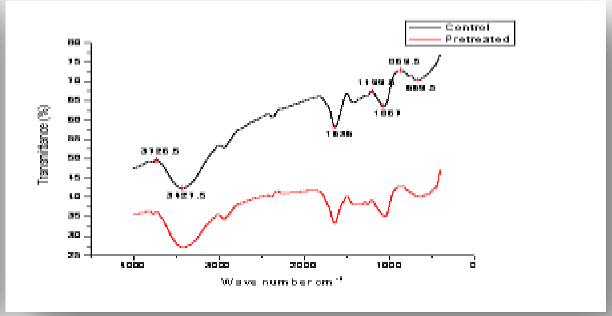
FTIR analysis



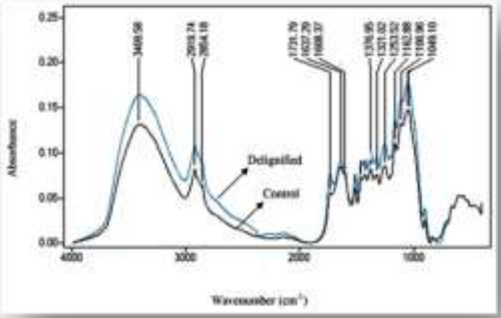
Ricinus communis



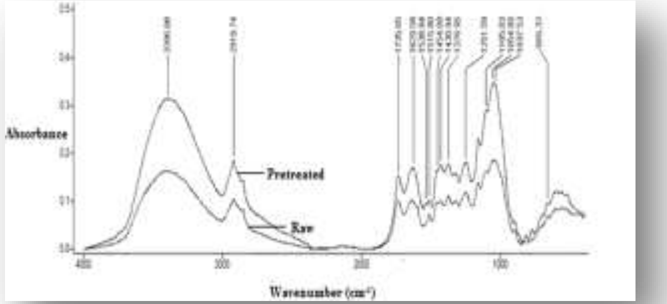
Lantana camara



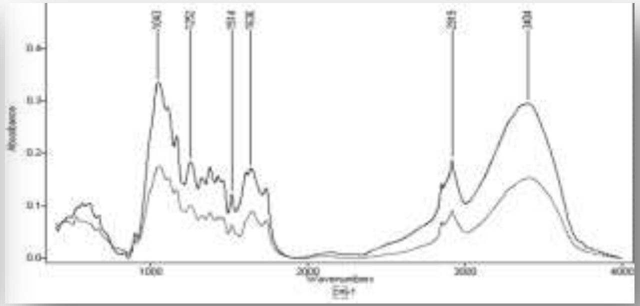
Bambusa bambos



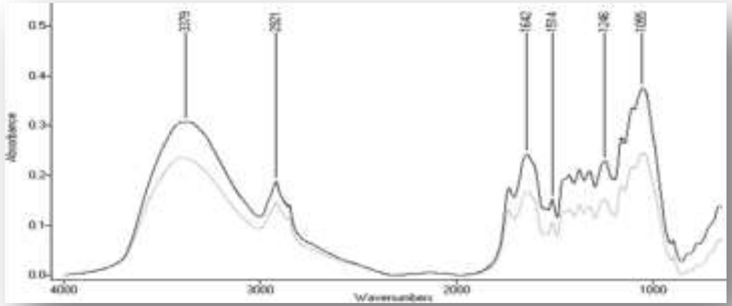
Kans grass



Pineapple leaf



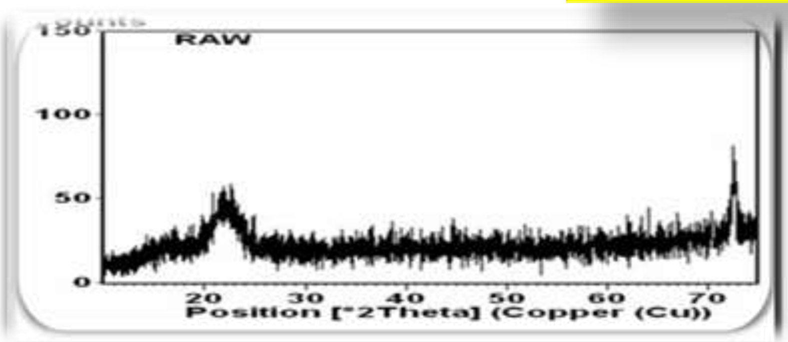
Sugarcane top



Mixture

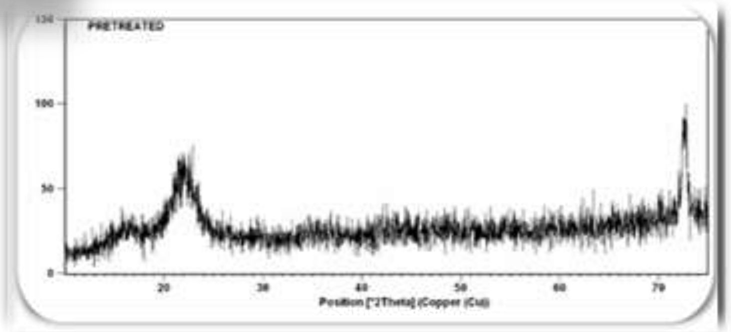
Wavenumber (cm^{-1})	Particular
3425-3300	OH Vibration
2919-2932	C–H methyl and methylene groups
1060-1262	O–H phenolic
626-1055	lignin

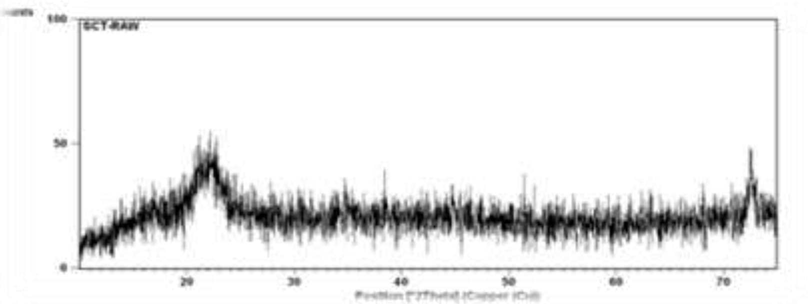
XRD Analysis



Control
Lantana camara

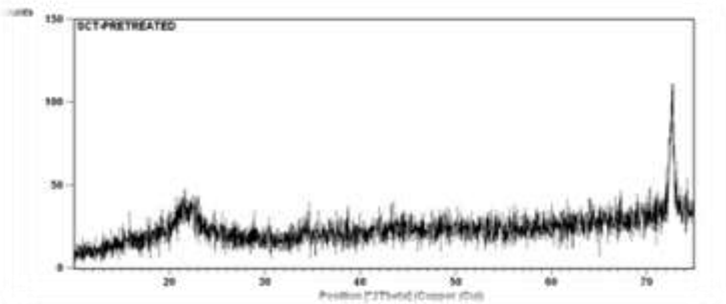
Pretreated
Lantana camara

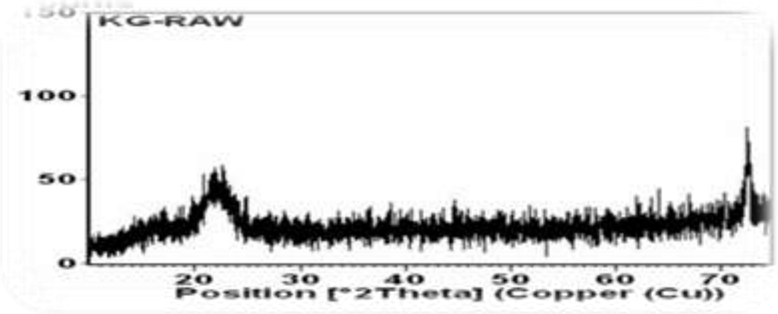




Control
Sugarcane top

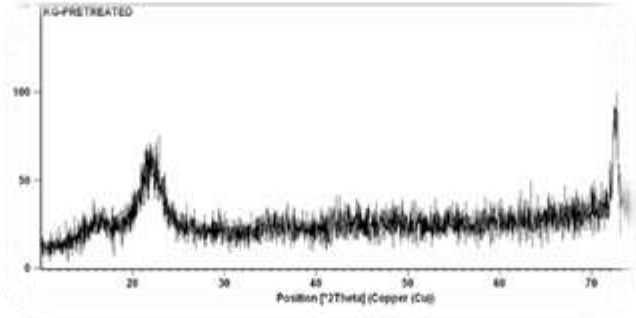
Pretreated
Sugarcane top



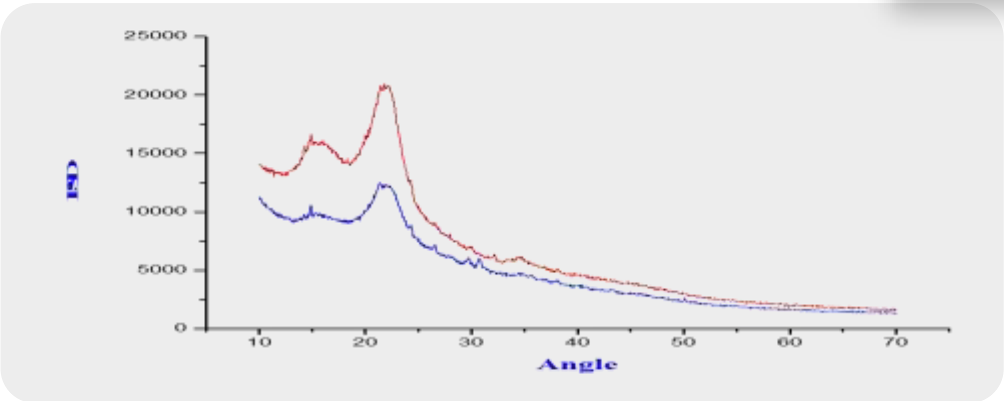


Control
Kans grass

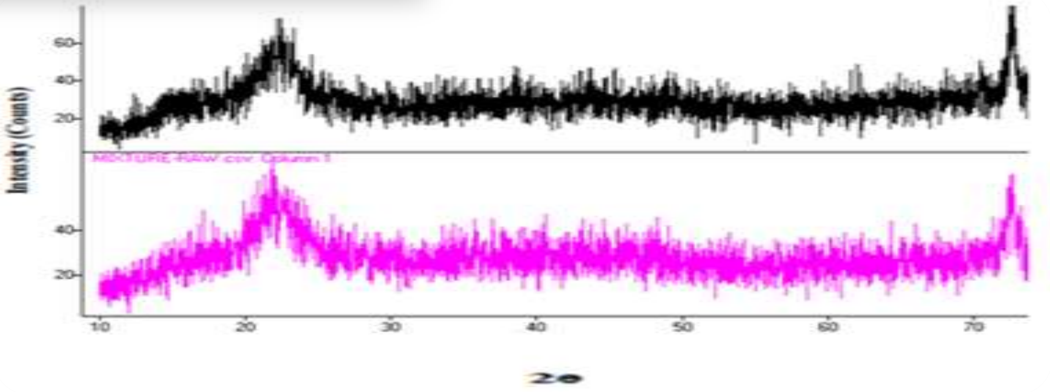
Pretreated
Kans grass



XRD Analysis cont...



Pineapple leaf



Mixture

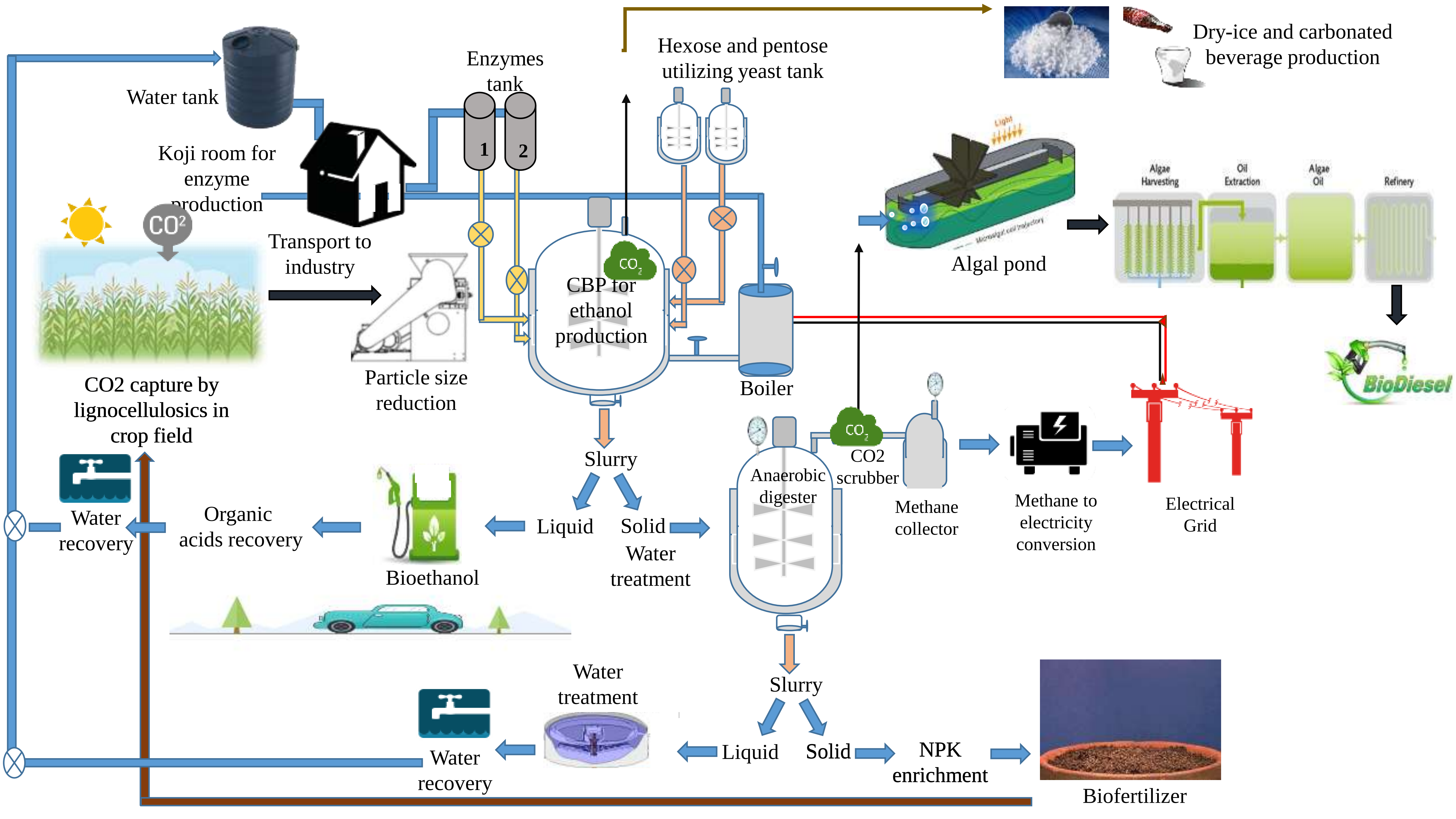
Lignocellulosic biomass	Increase in crystallinity (%)
Ricinus communis	6.82
Lantana camara	7.46
Kans grass	8.54
Bambusa bambos	4.62
Pineapple leaf waste	6.25
Sugarcane top	4.30
Mixture	3.66

Porosity Analysis by BET/BGH Analyzer

Biomass	Pore size (Before (b); After (a)) Angstrom	Pore volume (Before (b); After (a)) cm^3/g	% Delignification
Ricinus communis	189.20 (b); 297.98 (a)	13.01×10^{-3} (b); 20.50×10^{-3} (a)	75-80
Lantana camara	86.74 (b); 108.957 (a)	5.968×10^{-3} (b); 7.496×10^{-3} (a)	75-80
Kans grass	61.9 (b); 128.5 (a)	4.259×10^{-3} (b); 5.365×10^{-3} (a)	75-80
Pineapple leaf waste	120 (b); 134 (a)	4.26×10^{-3} (b); 6.57×10^{-3} (a)	75-80

Strategies to improve the ethanol yield from lignocellulosic biomass

Lignocellulosic biomass	Ethanol (%, v/v)				
	SHF	SSF	CBP	PCBP	SSCF
Rice straw	3.8	3.8	4.1	3.82	4.12
Wheat straw			1.72		
Banana	3.6	3.9	4.5	4.1	4.53
Ricinus communis	2.78	3.58	6.81	7.12	6.24
Lantana camara	2.51	3.38	6.5	6.9	6.95
Sugarcane top	3.21	6.02	5.91	5.96	7.5
Kans grass	3.5	6.3	4.9	7.8	8
Pineapple leaf waste	3.25	6.42	6.78	7.18	6.95
Mixture	3	5.14	7.52	7.65	7.5



Water tank
Enzymes tank
1
2
Hexose and pentose utilizing yeast tank
Dry-ice and carbonated beverage production
Koji room for enzyme production
CO2
Transport to industry
CO2
CBP for ethanol production
Boiler
Algal pond
Algae Harvesting
Oil Extraction
Algae Oil
Refinery
BioDiesel
CO2 capture by lignocellulosics in crop field
Particle size reduction
Slurry
Liquid
Solid
Water treatment
Anaerobic digester
CO2
CO2 scrubber
Methane collector
Methane to electricity conversion
Electrical Grid
Water recovery
Organic acids recovery
Bioethanol
Water treatment
Water recovery
Slurry
Liquid
Solid
NPK enrichment
Biofertilizer

Koji room facility for Enzyme Production

Boiler assembly → Distillation assembly

Biomass collection tank

Gantry system for lifting the immobilization tray

Established biomass pretreatment technology with different substrates

Bioresource Technology
Volume 212, July 2016, Pages 47-54

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Enzyme mediated biomass pretreatment and hydrolysis: a biotechnological venture towards bioethanol production

Check for updates

Rajiv Chandra Rajak [a] and Rintu Banerjee [b]

Execution model/ Prototype

Patents Filed

- **R**, **Banerjee**, A, Kuila, M. Mukhopadhyaya, "Enzymatic saccharification and fermentation of pretreated lignocellulosic raw material" (17/KOL/2012)
- **R**, **Banerjee**, M. Mukhopadhyaya, A, Kuila, "A method for enzymatic delignification of lignocellulosic raw materials" (126/KOL/2012)
- **R**, **Banerjee**, M.M. Ghangrekar et al., "Yellow laccase mediated delignification of lignocellulosic biomass" (201631005954 dt: 20.02.2016)
- **R**, **Banerjee** et al., "Production and application of hyperactive cellulase from a newly isolated strain of Aspergillus species (RB1313)" (201931042676 dt: 21.10.2019)

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Cheaper, quicker, pollution free—IIT Kharagpur gears up to redefine biofuel

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NEWS

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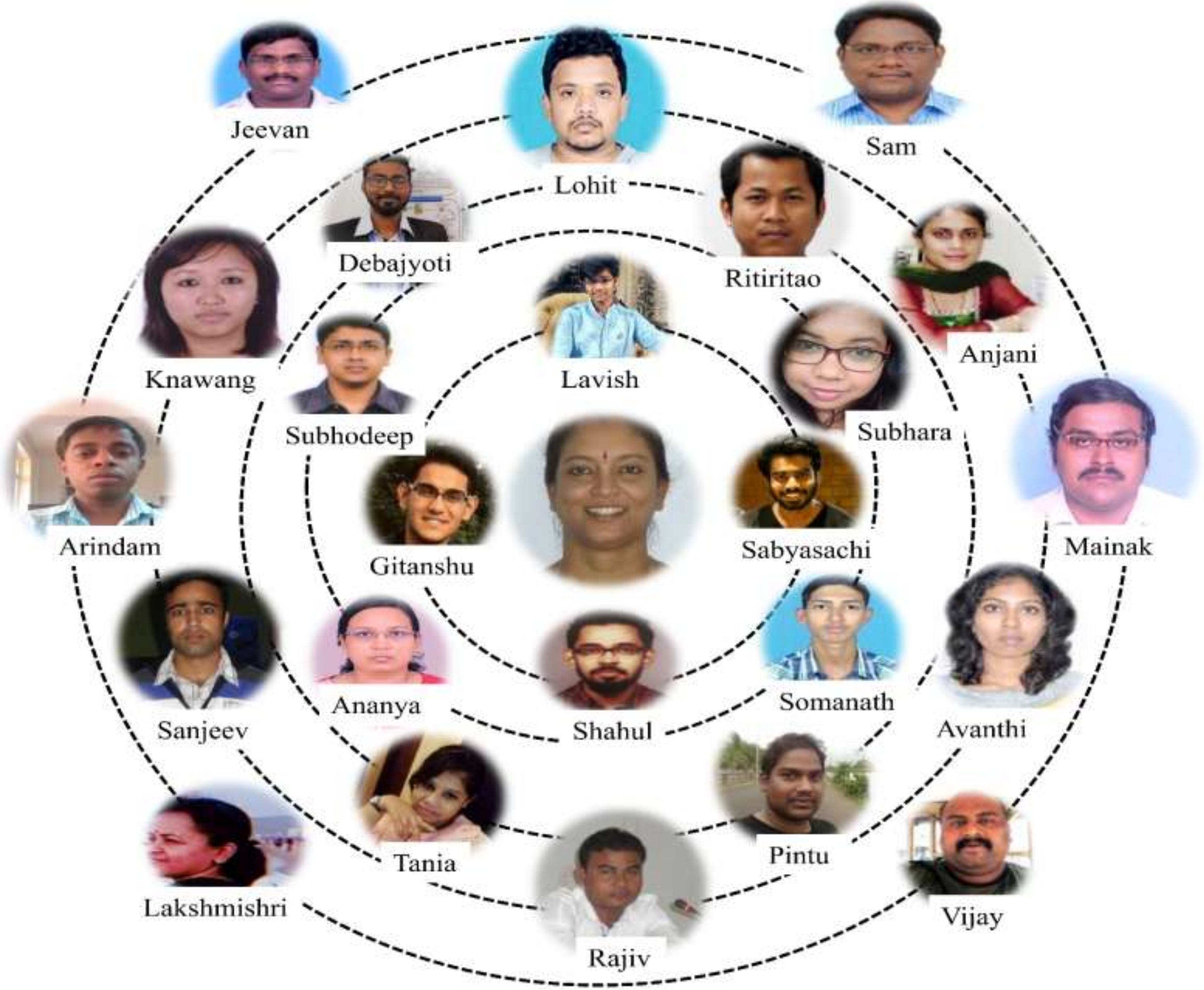
IANS | Kolkata

May 31, 2017 Last Updated at 17:42 IST

Microbial Biotechnology and Downstream Processing Laboratory

Biofuel Research Group



element
bio
CO2
friendly
energy
creative
renewables
solar energy
earth
solar
planet
growth
oxygen
nature
resource
pollution
power
natural
biogas
fuelgas
ecological
wind
renewable
greenhouse
recycle
energy security
water
turf
clean
water power
organic
tree
alternative
eco
environment
protect
coal-fired
global
fresh
peat
save
life
resourceful
recyclable
fossil
capacity
wood
efficient
fossil fuel
biofuel
flora
plant
ecology
rain forest
environmental
conservation
burn
industrial
emission
earth
tree
globe
clean
green
factory
turf
flora
puls
fuel
ozone

Thank You

green
oxygen
solar
clean
alternative
on
bio
biofuel
ecology
power
reduce
natural
nature
renewable
energy
recycle
save
organic
planet
resource
environment