يونيبرسيتي بروني دارالسلام
UNIVERSITI BRUNEI DARUSSALAM

Universitas Balikpapan

1st International Conference on
Renewable Energy and Sustainable Community Transformation (ICORESCT)
Hotel Swiss-bel Balikpapan
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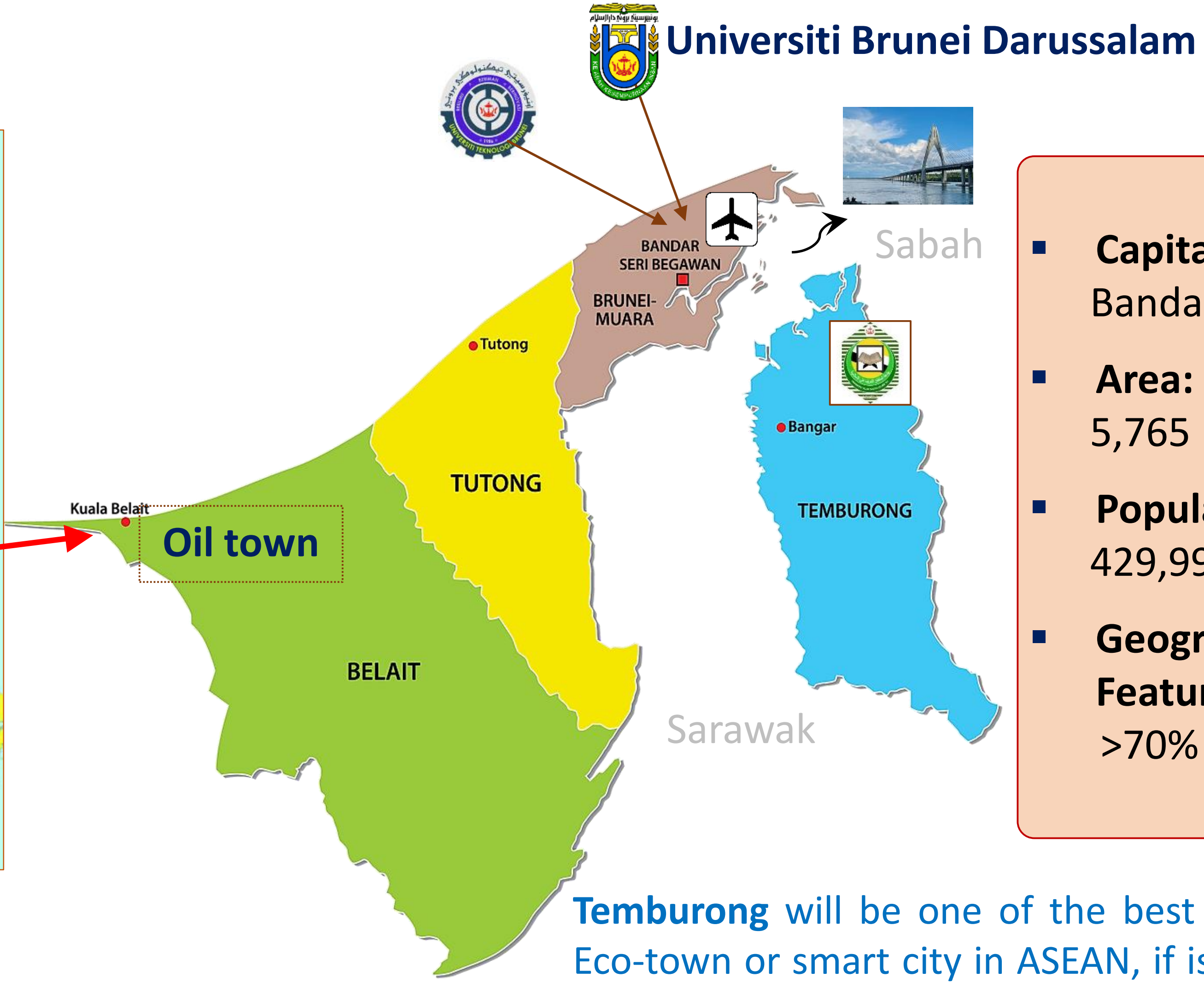
Prospects for Bio-refineries Production

Rosnah Abdullah
Assistant Professor, Applied Physics, Faculty of Science
Head of BSN Secretariat, Office of AVC Global Affairs
Universiti Brunei Darussalam

Brunei Darussalam



- **Capital:** Bandar Seri Begawan
- **Area:** 5,765 km^2
- **Population:** 429,999 (2021)[1]
- **Geographical Feature:** >70% forest

Temburong will be one of the best examples of an Eco-town or smart city in ASEAN, if is developed into an ecotown or smart city[2]

[1] *https://deps.mofe.gov.bn/SitePages/Population.aspx*
[2] *www.eria.org*



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Vision

To be an academic unit with an international character, where staff from different backgrounds and cultures can combine their talents for the common target to become a distinguished hub of excellence in teaching and research in Asia and beyond.

Our Mission

Offer high quality teaching and learning services.
Educate students to become highly competitive in the international markets.
Elaborate high quality research and engage our students into it.
Make a significant positive impact on society, locally, nationally and internationally and to fulfill our obligations to the people of Brunei Darussalam.

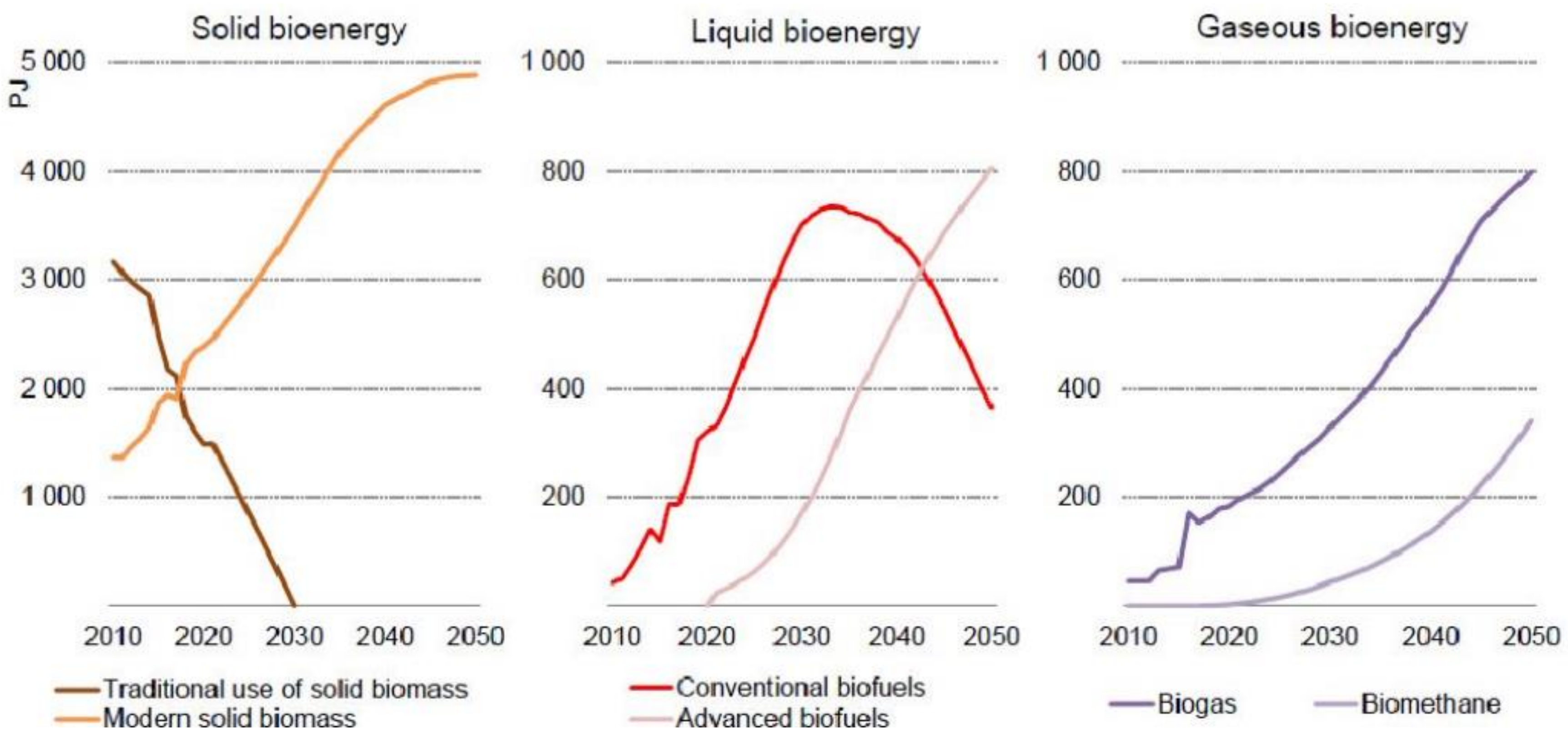
ubdfos FOS UBD **Visit: http://fos.ubd.edu.bn/fosweb/**

Sustainable Development Goals

https://sdgs.un.org/goals

Sustainable Development Scenario 2010-2050

Bioenergy



The growth in bioenergy should be accompanied by shift towards sustainable feedstocks and modern production pathways, which avoid negative effects on biodiversity and human health

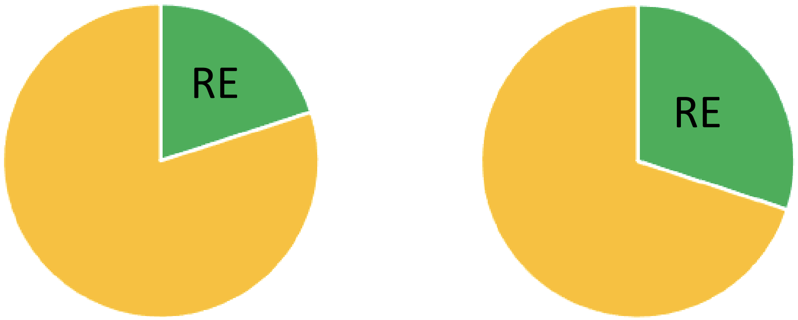
Francis J, 2023

Current Energy Scenario in Brunei

- Relies on fossil fuel for its national energy security and booming economy.
  - Hence, minimal interest in the use of RE
- Due to worldwide interest on RE and to diversify its energy sources and strengthen its energy security
  - Set out a *targets* on supply and consumption sides

SUPPLY SIDE

Increase Total Power Capacity Mix from RE

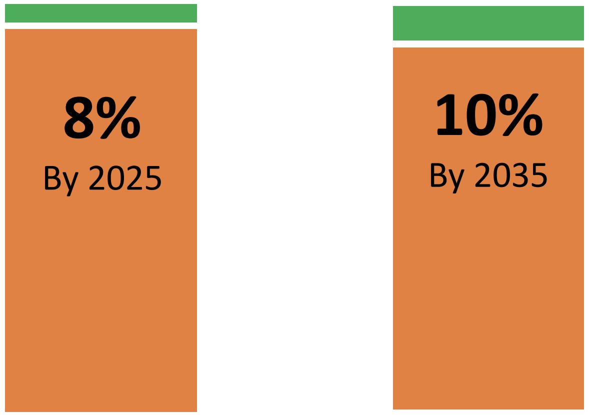


25 %
by 2025

30 %
by 2035

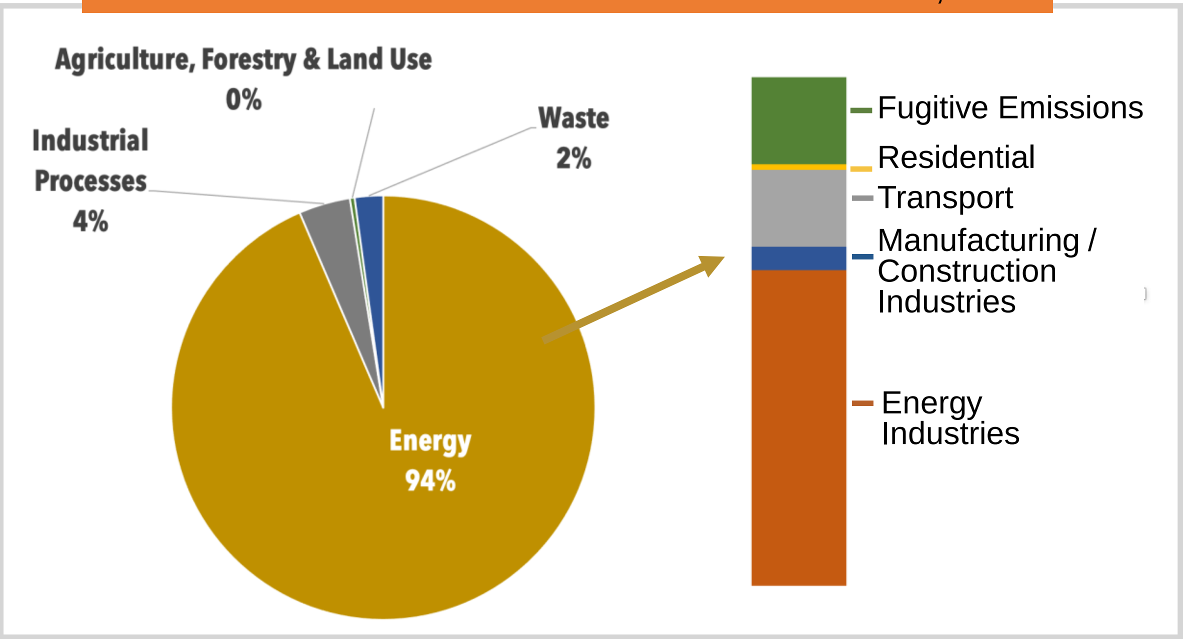
CONSUMPTION SIDE

Reduce Total Electricity Consumption

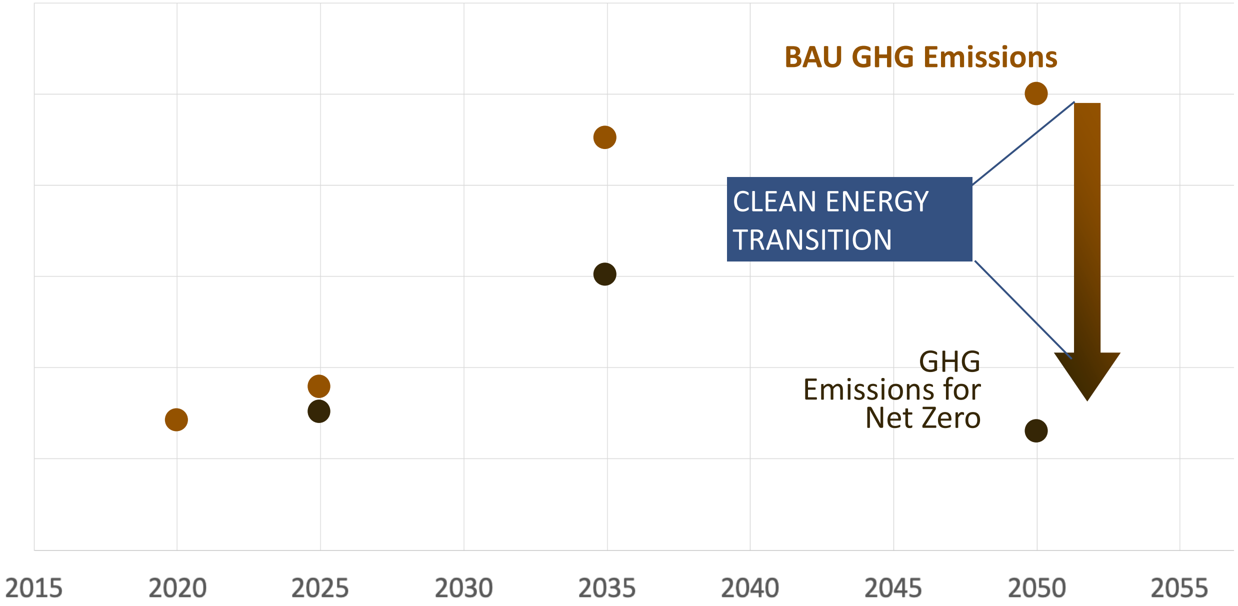


Brunei Energy White Paper, 2021 (revised)
Dept. of Energy, 2022

BRUNEI DARUSSALAM TOTAL GHG EMISSIONS, 2020



GHG EMISSIONS SCENARIOS



<u>Strategic Objective 3: Green Energy</u>

For the long-term energy security of Brunei Darussalam and its environment

in Brunei Energy White Paper

<u>The Brunei Darussalam National Climate Change Policy</u>

Potential to reduce up to 50% of the total GHG Emissions by 2035

PARIS AGREEMENT

<u>Nationally Determined Contributions</u>

Brunei Darussalam pledged to reduce 20% of its total GHG emissions from the BAU Levels by 2030

<u>COP26</u>

-Expressed intention towards Net Zero by 2050
-Pledged to accelerate Renewable Energy deployment

Dept. of Energy, 2022

Brunei to introduce mandatory carbon reporting in 2021

The National Council on Climate Change launches its first policy document to reduce greenhouse gas emissions

Rasidah Hj Abu Bakar

JULY 25, 2020

BANDAR SERI BEGAWAN – Brunei will make it mandatory for industrial greenhouse gas emitters to report their carbon footprint from next year, a move towards combating climate change after the country recorded rising temperatures and the highest number of forest fire incidents in 10 years.

Mandatory carbon reporting is one of 10 strategies outlined in the first **Brunei Darussalam National Climate Change Policy (BNCCP) document** that was unveiled on Saturday.

The government is expected to draft legislation requiring "all facilities and agents that emit and absorb greenhouse gases" to submit their carbon data on a monthly and yearly basis.

Carbon reporting is aimed at promoting transparency of greenhouse gas emissions and helping Brunei transition into a low-carbon nation through better monitoring.

Brunei has one of the highest annual carbon footprint per person in the region at 10 tonnes of carbon dioxide, which needs about 200 trees to offset.

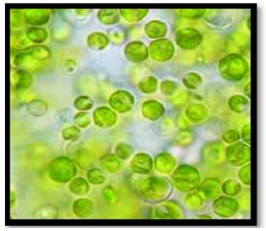
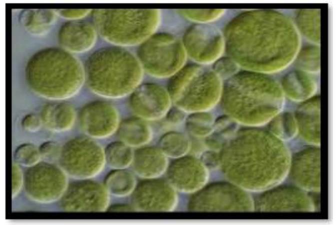
Speaking during the launch of the climate change policy document, development minister YB Dato Seri Setia Ir Hj Suhaimi Hj Gafar said the carbon inventory will be used as a tool to ensure successful climate change mitigation and adaptation.

Biofuel Generations

- 1st generation
  - Food crops (e.g. Palm oil or Corn or Maize to biodiesel)
- 2nd generation
  - Lignocellulosic waste to fuel (producing bioethanol)
  - (e.g. Rice husk to bio-oil via pyrolysis ; Waste cooking oil to bio-diesel)



- 3rd generation – Algae feedstocks

- 4th generation – Bio-engineered organisms?

Issues Arise from Biofuels

- Food vs. Fuel debate – 1st generation
  - Land could be used for growing food crops (food security)
  - Food should be utilised in vital places
- Land usage competition – 2nd generation
  - Food crops vs non-food crops (eg. growing Jatropha, Switchgrass, Acacia, etc)
  - Sustainability
- Expensive (at the moment) – 3rd generation
  - Need a lot of water and nutrients; potential contamination

Types of Biomass

- Biomass
  - Virgin resources (Section 2.2)
    - Sugar — Sugar cane, sugar beet
    - Starch — Rice, wheat, potatoes
    - Forest resources — Wood, bamboo, sasa
    - Hydrocarbon — Eucalyptus leaf, etc.
    - Oil/fat crops — Rapeseed, soybean, etc.
    - (Ocean) — Kelp, etc.
    - (River and lake)
    - (Microorganism)
  - Residues (Section 2.3)
    - Wood residues
      - Leftover treetop/branch
      - Wood from thinning
      - Factory residues
      - Construction residues
      - Waste paper
    - Agricultural residues
      - Rice straw, wheat straw
      - Bagasse
      - Other agricultural residues
    - Livestock residues
      - Livestock excrement
      - Livestock carcass
    - Residues from fishery
      - Fish processing residues
      - Released fishes
      - Chitin
    - Industrial residues
      - Pulp sludge
      - Animal/plant residues
      - Waste oil/fat
    - Non-industrial residues
      - Municipal refuse
      - Sewage sludge

Minami et al, 2005

Biomass Composition

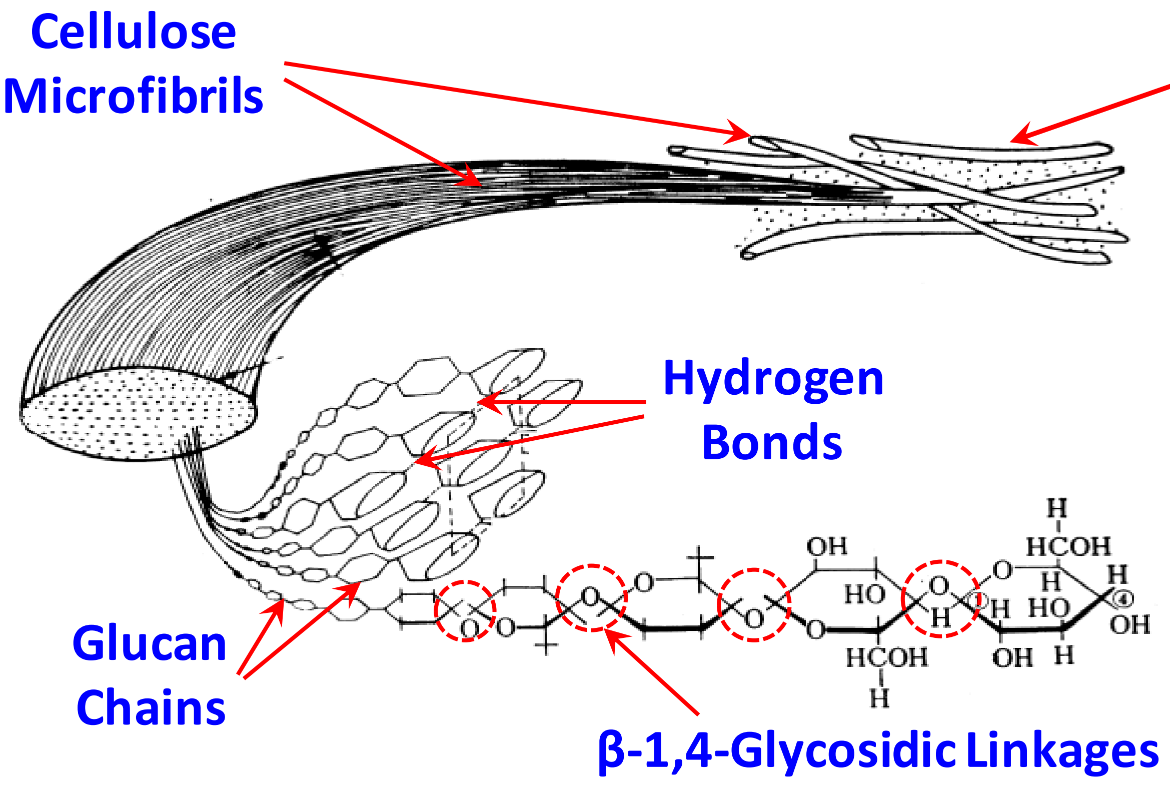
- Any recent material of biological origin and includes plant materials such as trees, grasses and agricultural crops, as well as animal manure and municipal biosolids (sewage).

- Photosynthesis process:

$$CO_2 + H_2O + \text{light} \rightarrow (CH_2O)_x + O_2$$

- The sugars produced are stored in polymers such as cellulose, hemicellulose and starch.
- Biomass is composed of 65–85wt% sugar polymers (mostly cellulose and hemicellulose) and 10–25wt% lignin.
- Other biomass components: triglycerides, sterols, alkaloids, resins, terpenes, lipids and inorganic minerals.

Structure of Lignocelluloses

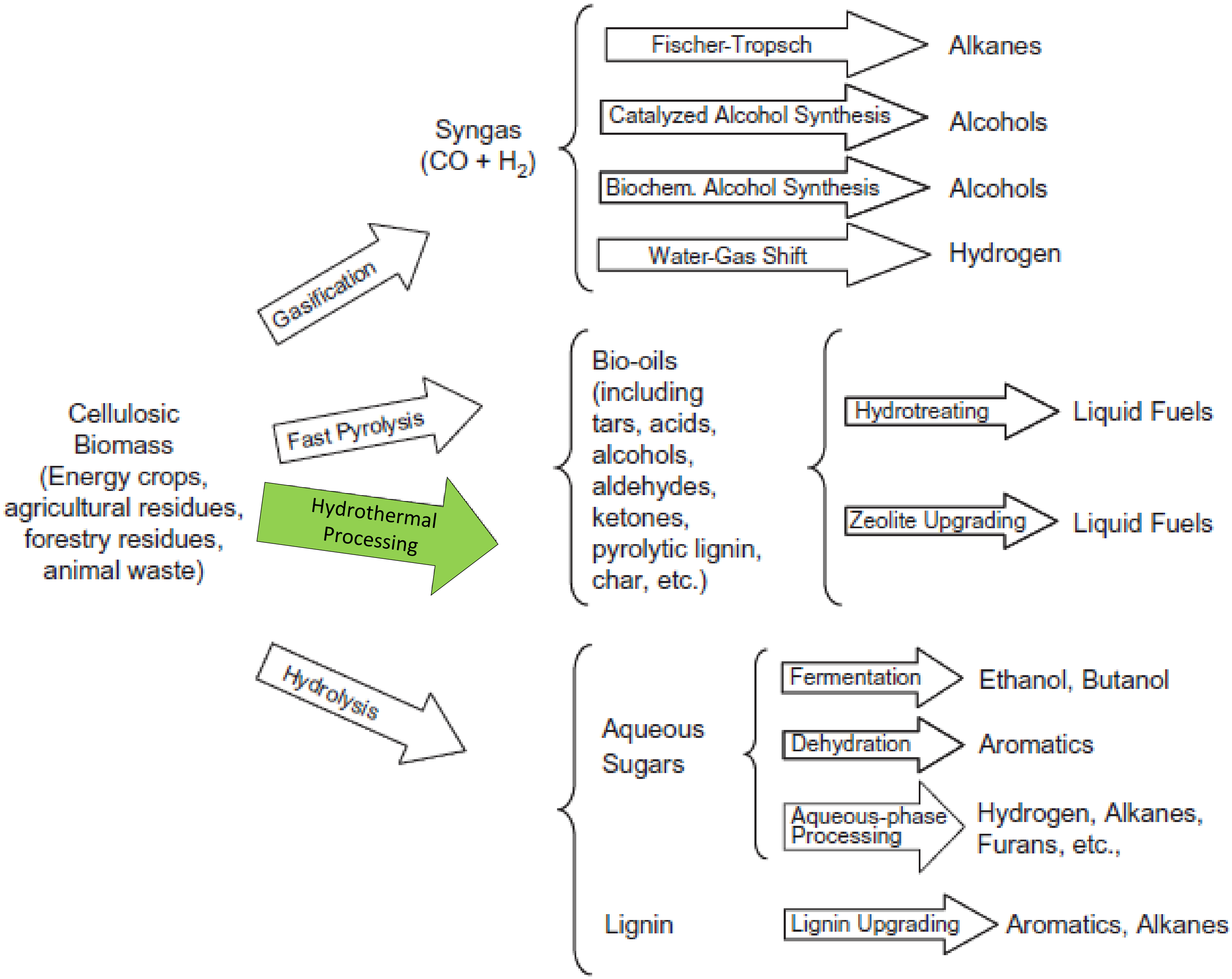


Cell Wall Substances

- ***Hemicelluloses***
  - **Xylan**
  - **Glucomannan**
- ***Lignin***
  - **Syringyl Propane Unit**
  - **Guaiacyl Propane Unit**
  - ***p*-Hydroxyphenyl Propane Unit**
- ***Others***
  - **Extractives**
  - **Starch**
  - **Protein**
  - **Inorganic Constituents**
  - **etc.**

Wood Chemistry (1968) (in Japanese)

Pathways for Cellulosic Biomass Conversion to Fuels



Hydrothermal Liquefaction for Extraction of Bio-refineries Products

Lignocelluloses

↓

Hydrothermal

•*Sub-/Super-critical*

•*Hot-compressed water*

↓

Bio-refinery Process

↓

Bio-refinery Products

Hydrothermal Conditions

- Elevating temperatures and pressures of water
- Affect the properties of water:
  - Density *decreases*
  - Dielectric constant *decreases*
  - Hydrocarbon solubility *increases*

↓

Non- toxic products

Potential Biomass Resources in Brunei

- Net Primary Production(NPP) of biomass productivity for Brunei is 8.5 tC/ha/yr as compared to global average NPP of 3-4 tC/ha/yr.[1]
- Biomass is considered the 2nd important source of energy in Brunei and it is mainly classified into two groups[2]

1. **Agricultural crops and forests**
    - Example: Acacia is a fast-growing invasive plant which is a good source of high quality lignocellulosic biomass.[3]
2. **Solid Wastes like municipal wastes, animal residues, forest and agriculture wastes, bioprocess wastes, paper wastes, food wastes, etc.**
    - Brunei imports 80–85% of its food requirements, currently, Brunei is cultivating its own rice to be self-reliant in this crop. Other locally grown crops include sweet potato, banana, cassava, coconut, pineapple and vegetables.
    - Agricultural waste such as rice straw, rice husks, and urban forestry residues such as wood trimmings, wood chips etc.

[1]*IRENA (2021) International Renewable Energy Agency*
[2]*Malik (2011)* Assessment of the potential of renewables for Brunei Darussalam
[3]*UBD News: https://ubd.edu.bn/news-and-events/news/2018/12/18/partners-in-renewable-energy-research-key-component-for-green-future/*

Potential Biomass Resources: Woody Biomass/Agricultural Wastes

Various Agricultural Solid Wastes (Wt%)			
	Annual Production ($x10^{-6}$ million tons/yr)	Energy Content (MJ/Kg)	Energy Potential ($x10^{-3}$million GJ/yr)
Coconut shell	11.8	19.4	0.229
Coconut fiber	25.1	19.85	0.498
Corn fiber	128.3	17.25	2.213
Rice husk	351.2	16.37	5.749
Saw-dust		21.5	

Tun et al., 2019

Chemical Composition of Various Wood Species

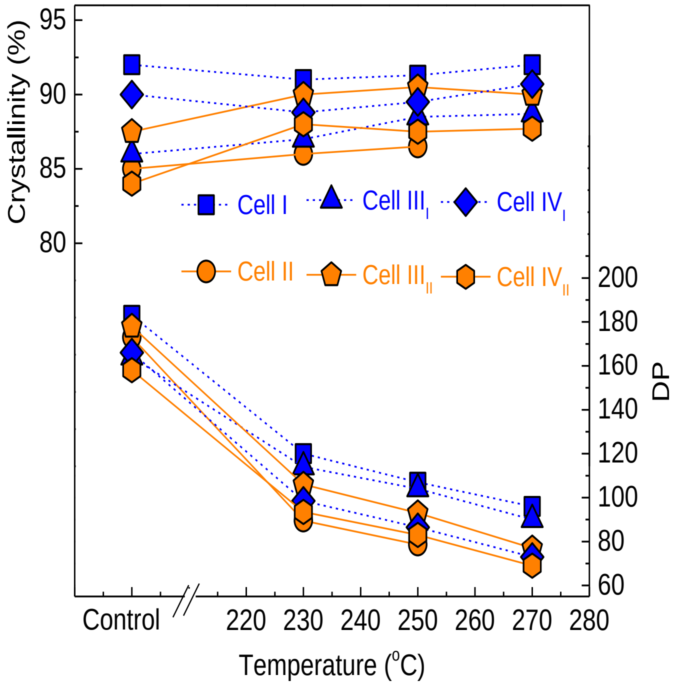
Wood species	Holocellulose (%)	Lignin (%)	Extractives (%)	Moisture (%)	Ash (%)
Keruing Bulat	67.1	42.1	6.73	1.80	0.30
Kapur Bukit	69.7	37.7	9.62	2.10	2.30
White Meranti	73.4	33.8	9.93	1.20	1.70
Yellow Meranti	73.1	29.1	9.62	2.10	0.60
Red Meranti	72.0	44.9	9.48	2.00	0.60
Meranti Majau	73.6	32.9	9.84	0.90	0.40
Alan Batu	71.9	41.1	9.39	0.80	0.01
Acacia Mangium	69.4	38.9	8.73	3.10	1.00
Kempas	68.1	41.9	9.59	2.30	0.40
Belian	72.8	37.3	8.43	1.50	0.40

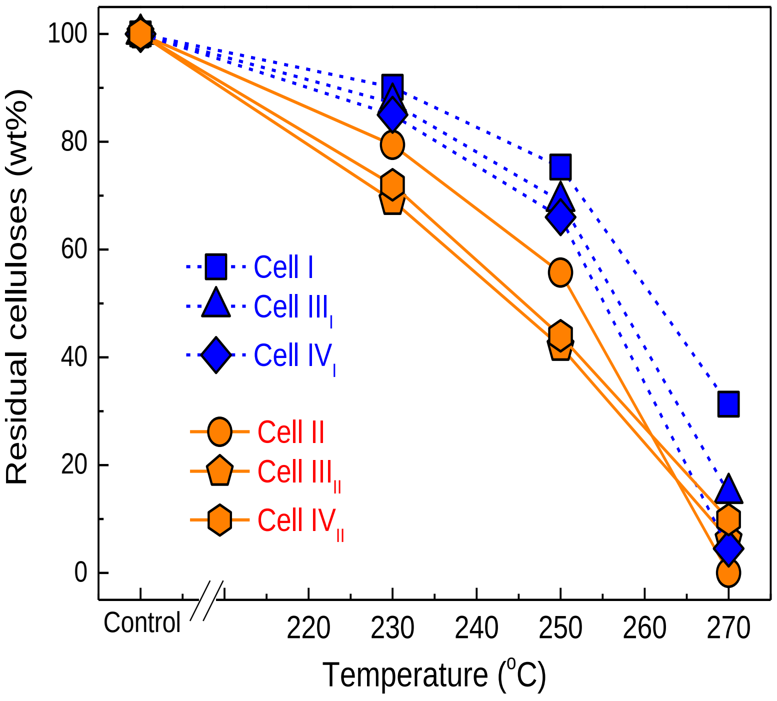
N. A. H. Morni et al. (2018), pp. 1-4, doi: 10.1049/cp.2018.1580.

Degradation of Cellulose Allomorphs in HTL at 230-270°C/10MPa/15min

- Modifying celluloses (I, II, III_I, III_{II}, IV_I, and IV_{II}) structure could be a useful way to enhance the accessibility of cellulose towards hydrolysis.

- Optimum condition using semi-flow HTL on lignocellulosic biomass was 270˚C/10MPa/15min for the decomposition of native cellulose.



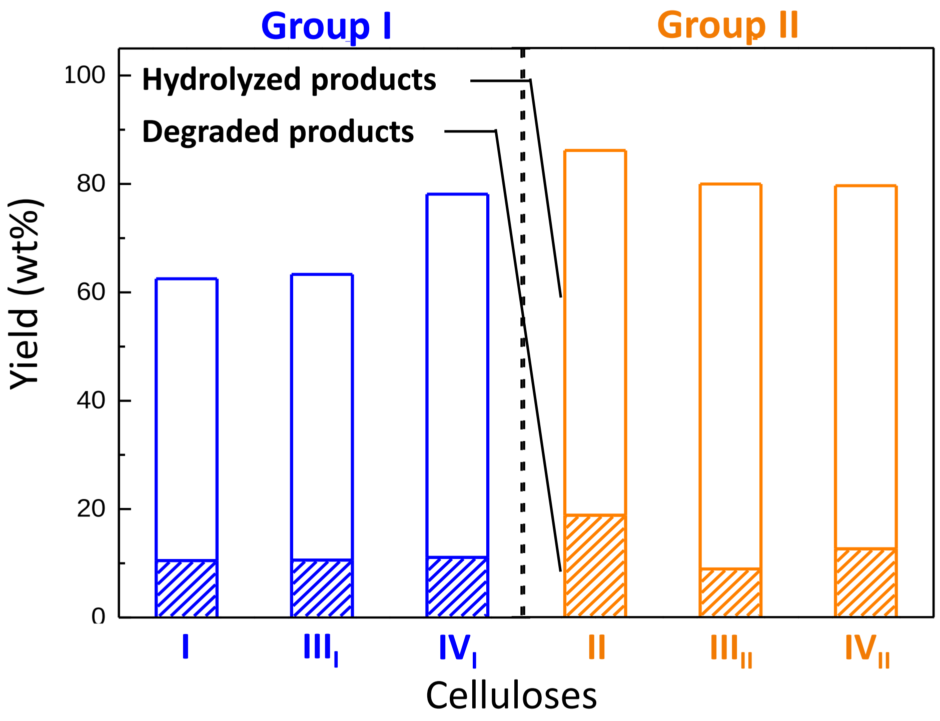


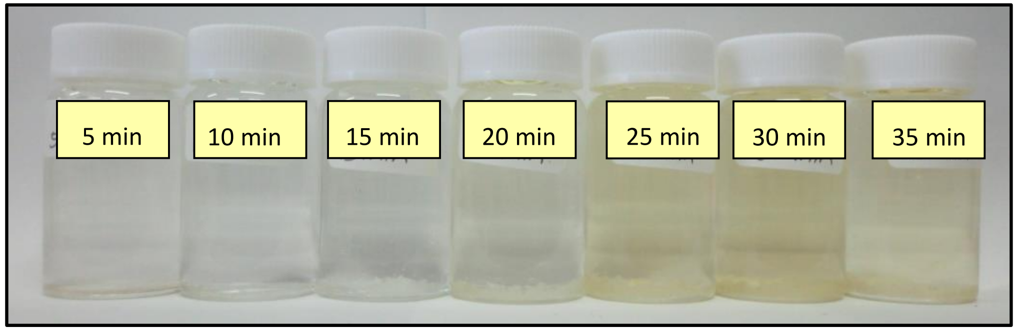
- **Group I** (Cell I, Cell III_I, Cell IV_I) & **Group II** (Cell II, Cell III_{II}, Cell IV_{II}) **celluloses**
- Significant DP decrease for celluloses in group II.
- The DP of cellulose in group I is higher than that in group II.

- Cell I has the highest resistant against decomposition.
- Cell II, cell III_{II} and cell IV_{II} decomposed the most as compared with cell III_I and cell IV_I, indicating that, group I has higher resistance to decompose than group II celluloses.

Abdullah R et.al, 2013

Degradation of Cellulose Polymorphs in HTL at 270°C/10MPa/15min





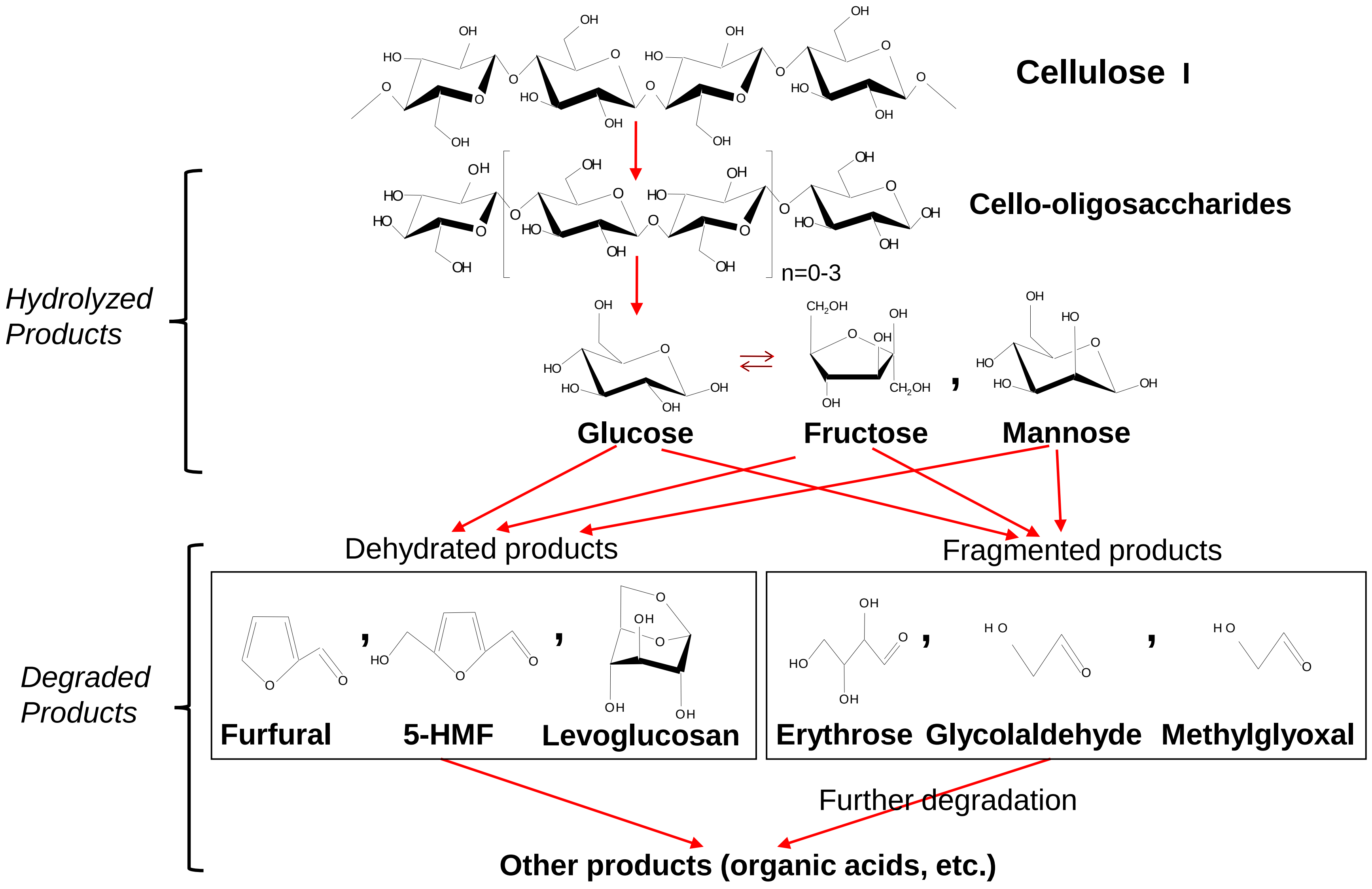
Cell IV$_I$ at 270˚C/10MPa/15min

Abdullah R et.al, 2014

- >50 wt% hydrolyzed products at 270 ˚C/10 MPa/15 min.
- Group II celluloses have more decomposed products (hydrolyzed and degraded) than that in group I

- More hydrolyzed products indicate the treatment condition being appropriate for hydrolysis, besides its resistance to decompose.
- The treatment can be used as viable decomposition media for celluloses at which under the given treatment conditions, cellulose is more readily hydrolyzed with less degraded products.
- Group I celluloses has more resistance to decompose than those in group II.

Cellulose Decomposition Pathways

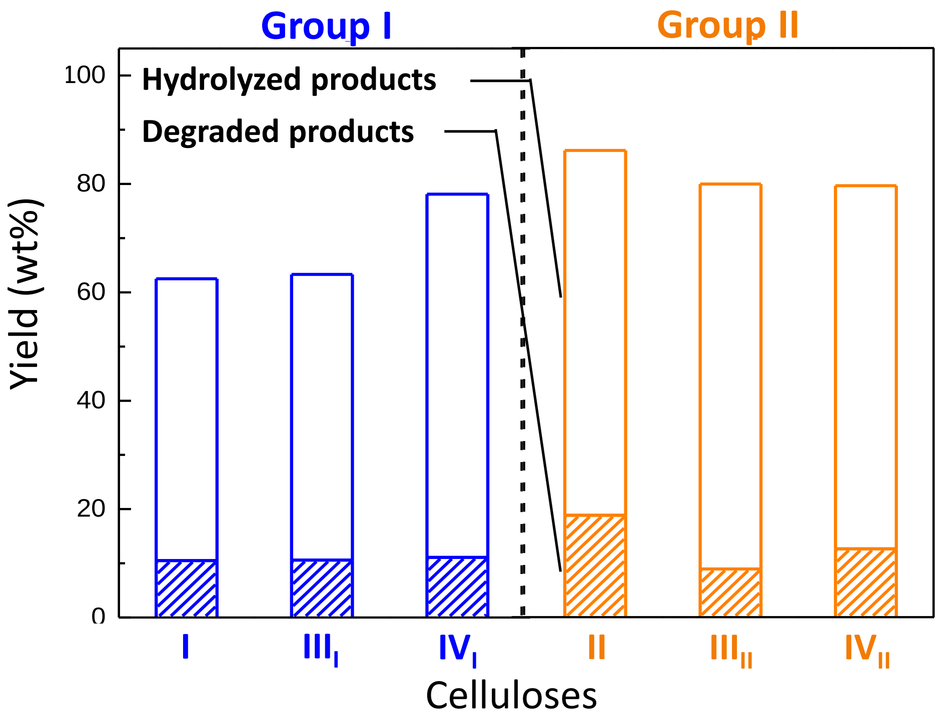


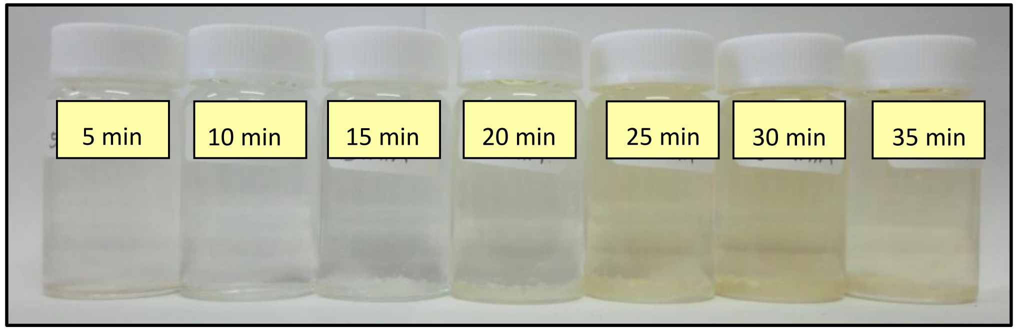
Abdullah et al, 2014

Life Cycle Assessment (LCA)

- Fossil fuel depletion, climate change and global energy demands have given rise to a need to find suitable bio-substitutes for products currently obtained from fossil sources.
- Development of bio-refinery processes for the production of biofuels and bio-products with lower global warming potential is crucial.
- Bio-crudes from lignocelluloses are increasingly being used in attempts to reduce the environmental impacts as to ensure energy security as well as sustainability in many parts of the world.
- The growth in bioenergy should be accompanied by a shift towards sustainable feedstock and modern production pathways, which avoid negative effects on biodiversity, human health and environment.
- Environmental assessment on various categories such as global warming potential, ozone impacts, toxicity and carcinogenic impacts etc. are necessary.
- Compliance with country's policy to have LCA reports

Degradation of Cellulose Polymorphs in HTL at 270°C/10MPa/15min





Cell IV_I at 270˚C/10MPa/15min

Abdullah R et.al ,2014

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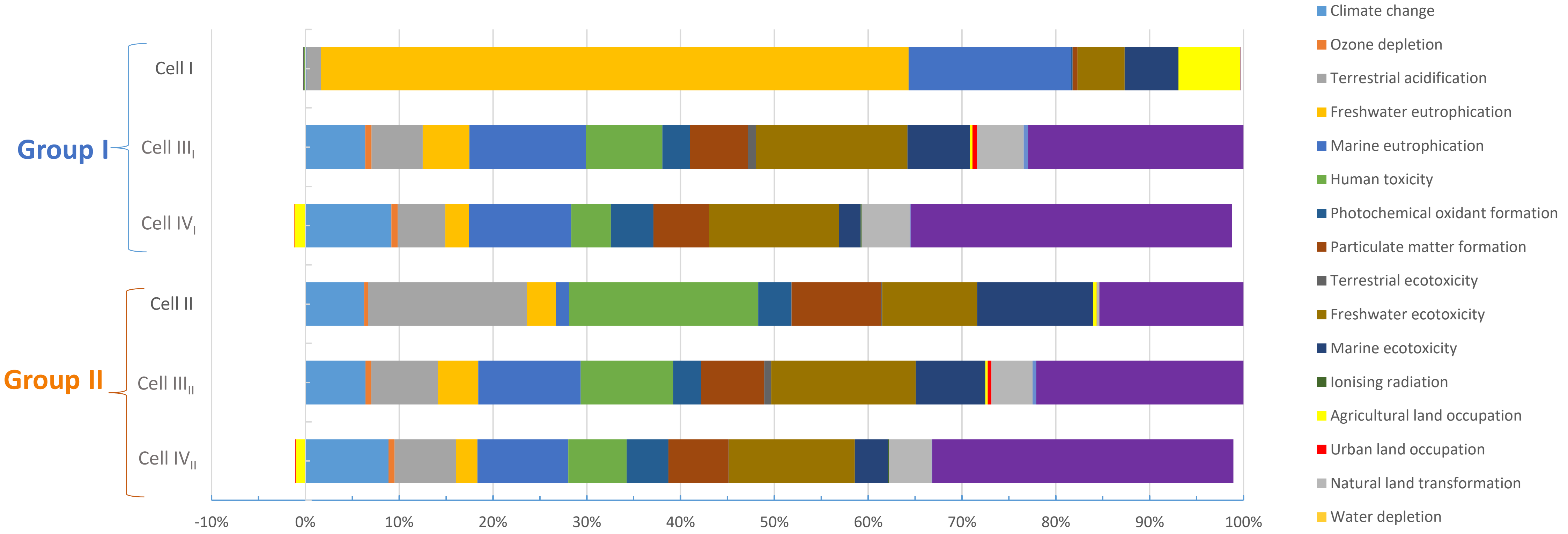
LCA of Cellulose Allomorphs Preparation



The process contribution analysis on various impact categories for production cellulose allomorphs. Left to write color order of each bar matches the top-bottom order of the legend. (excluding Electricity usage in the inventory)

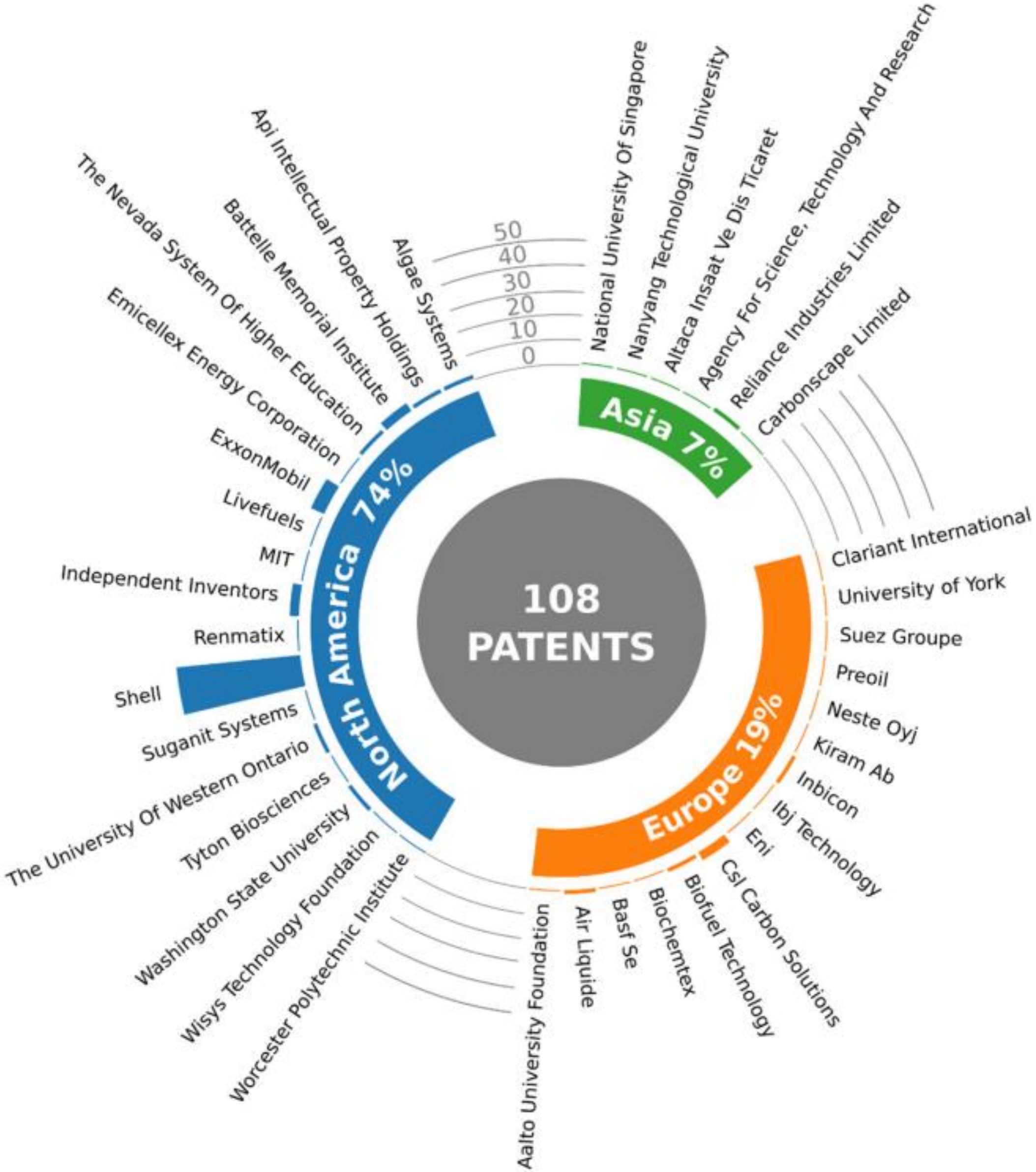
=> Identify the hotspots for the process of preparing cellulose allomorphs

HTL of Biomass from Principal Component Analysis of International Patents

- The methodology is based on traditional methods such as NLP algorithms to collate relevant inputs from the patent claims section. In this way, we access the most valuable technical information.
- Apply the PCA algorithm to measure the innovation intensity for different techniques.
- Recent literature reviews reported that technologies for biofuel production composed of thermo-bio-chemical processes and biomass combustion via coal-fired technologies are emerging, as well as, studies in biophotolysis, photo-fermentation, dark fermentation, and hybrid systems for bio-hydrogen production are considered emerging.
- Currently, in international patents, techniques such as **microwave co-processing** are a topic of interest to current inventors.
- From a hardware processing perspective, **batch reactors** dominate the scientific research studies, while **continuous processing is encouraged**.
- Studies investigating slurry viscosity and its control through **catalysts addition** such as ammonia or carboxymethyl cellulose have attracted attention.
- Scientists are still to **find solutions posed by environmental issues** associated with the biomass volumes required to facilitate this green energy transition

Silviu et al, 2022

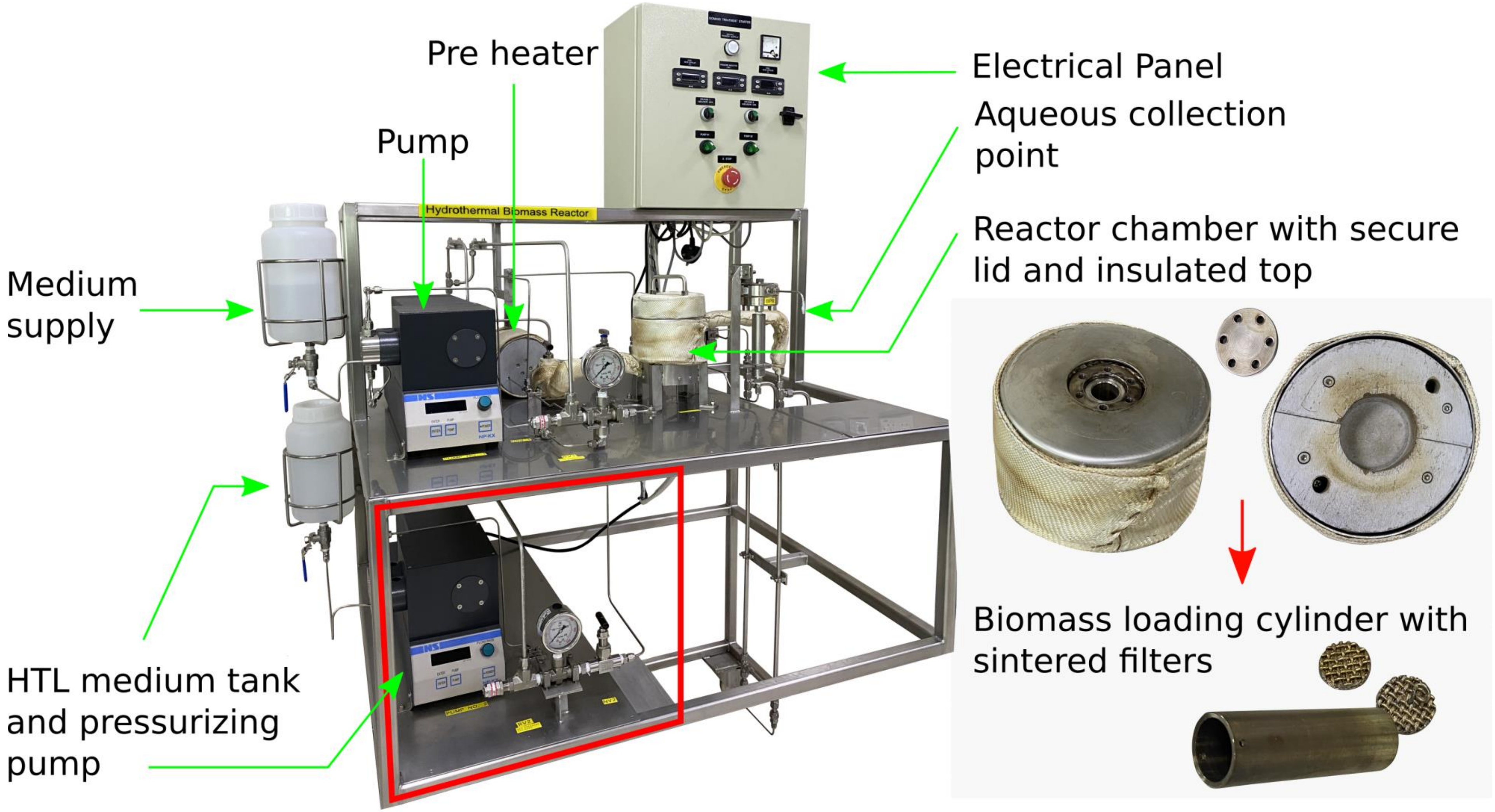
The Breakdown of Filing of Patent Dataset by Region



- Surrounding the figure are the patent owner names.
- The bars are a measure of the number of filings per inventor, where 0 to 50 is the guidance scale.

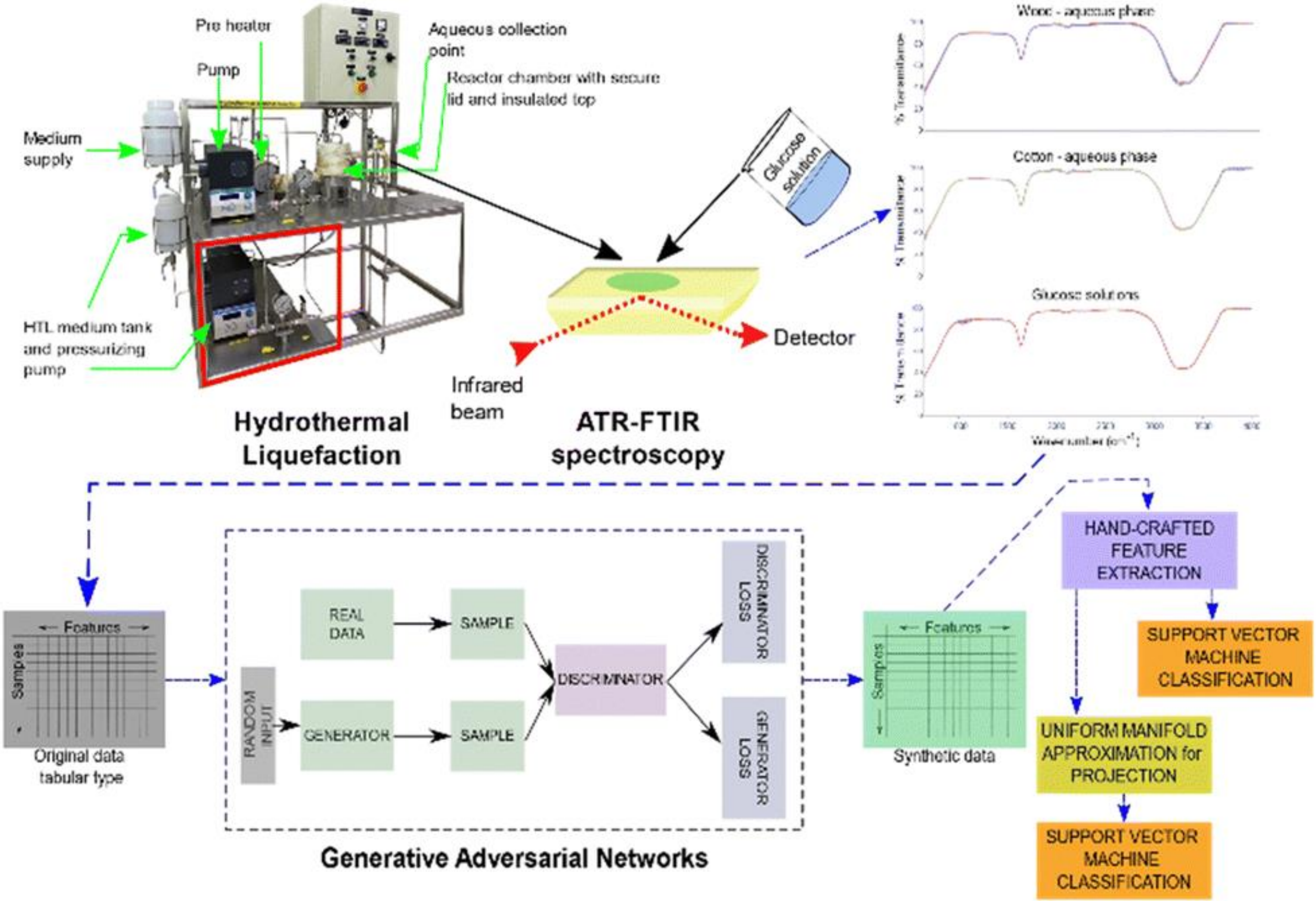
Silviu et al, 2022

Hydrothermal Liquefaction Process/System



Silviu et al. 2022

Enhancing Glucose Classification in Continuous HTL through Generative AI and IR spectroscopy



Silviu et al. 2023

Alkaline Treated Wood and HTL Tandem Processes

A 4% NaOH pretreatment *Dipterocarpus Caudatus* wood increased the production of a fermentation sugar, glucose, by 1.8-fold (equivalent to 90 g/L) and facilitated faster recovery times compared to biomass treated only with HTL .

Experiment	Sugar type	Estimated total/ wt%
Raw wood; HTL at 210°C and 0.2 MPa	Arabinose	2.34 ± 0.02
	Cellobiose	0.18 ± 0.02
Raw wood; HTL at 210°C and 6 MPa	Xylose and/or mannose	37.75 ± 3.74
	Glucose	23.35 ± 0.95
Alkaline treatment; HTL at 210°C and 0.2 MPa	Rhamnose	1.34 ± 0.02
Alkaline treatment; HTL at 210°C and 6 MPa	Glucose	41.45 ± 0.76

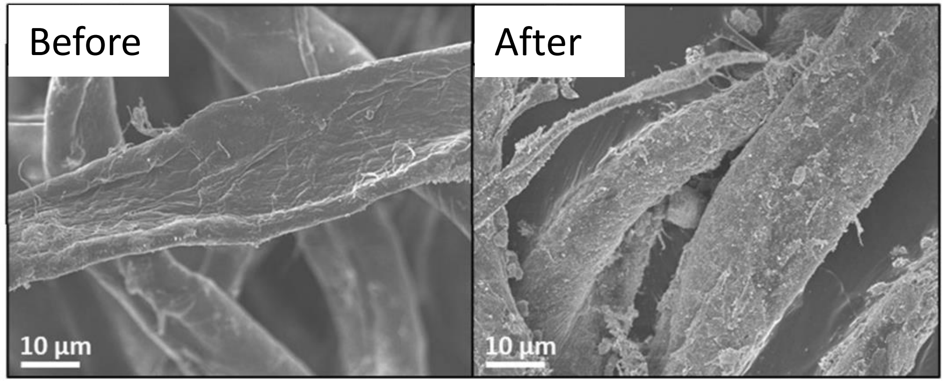
Silviu et al. 2022

Biohydrogen Production from Photodecomposition of Various Cellulosic Biomass Wastes using Metal-TiO2 Catalysts

Lignocellulose biomass wastes + *Metal – TiO2 *(Pd > Cu > Ni = Ce)*

Photocatalysis ↓

Biohydrogen



Photocatalysis of cotton linter

The properties of the celluloses and the yield of H2 within 3hr using 0.3% Pd/TiO2 catalysts

Biomass	Biomass sources	α-Cellulose, %	Hemicellulose, %	DP	CI, %	H_2 yield, µmol
Cellulose	Cotton linter	98.9	0.50	176	87	131 ± 0.04
Cellulose	Coconut husk	96.4	3.6	77	45	38 ± 0.01
Holocellulose		76.8	23.2	95	57	65 ± 0.02
Cellulose	Fern fiber	73.1	26.9	90	42	6 ± 0.00
Holocellulose		66.0	34.0	81	59	24 ± 0.01

-Concentrations of hemicellulose affecting the rate of H2 production due to the release of acetic acid during photodecomposition and accelerated the hydrolysis.

-Sugar fractions (glucose and fructose) from HTL of cotton linter cellulose improved H2 yield, suggesting the rate limiting step of the reaction is the dissociation of β(1→4)- glycosidic bonds to form sugar monomers

Syahidah et al. 2020

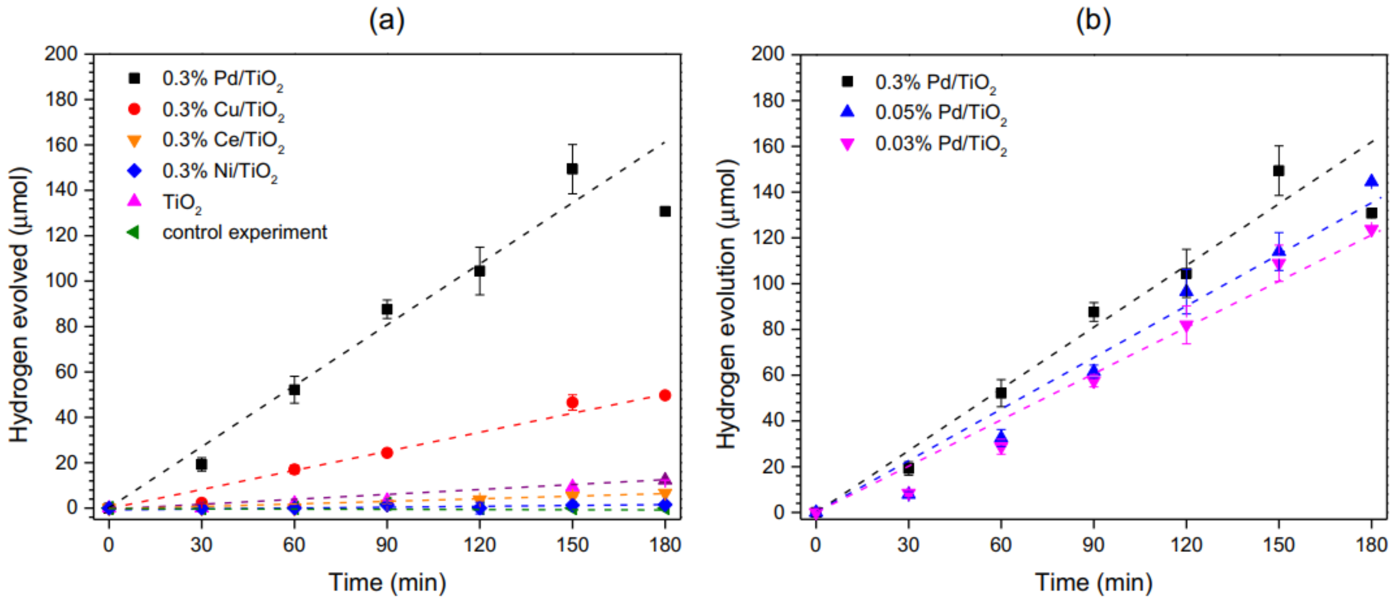


Fig. 7 (a) H_2 production from direct photocatalytic degradation of cellulose using 0.3% metal/TiO_2 catalysts in comparison to TiO_2. (b) H_2 production from photodecomposition of cellulose as a function of time over Pd/TiO_2 at different metal loading

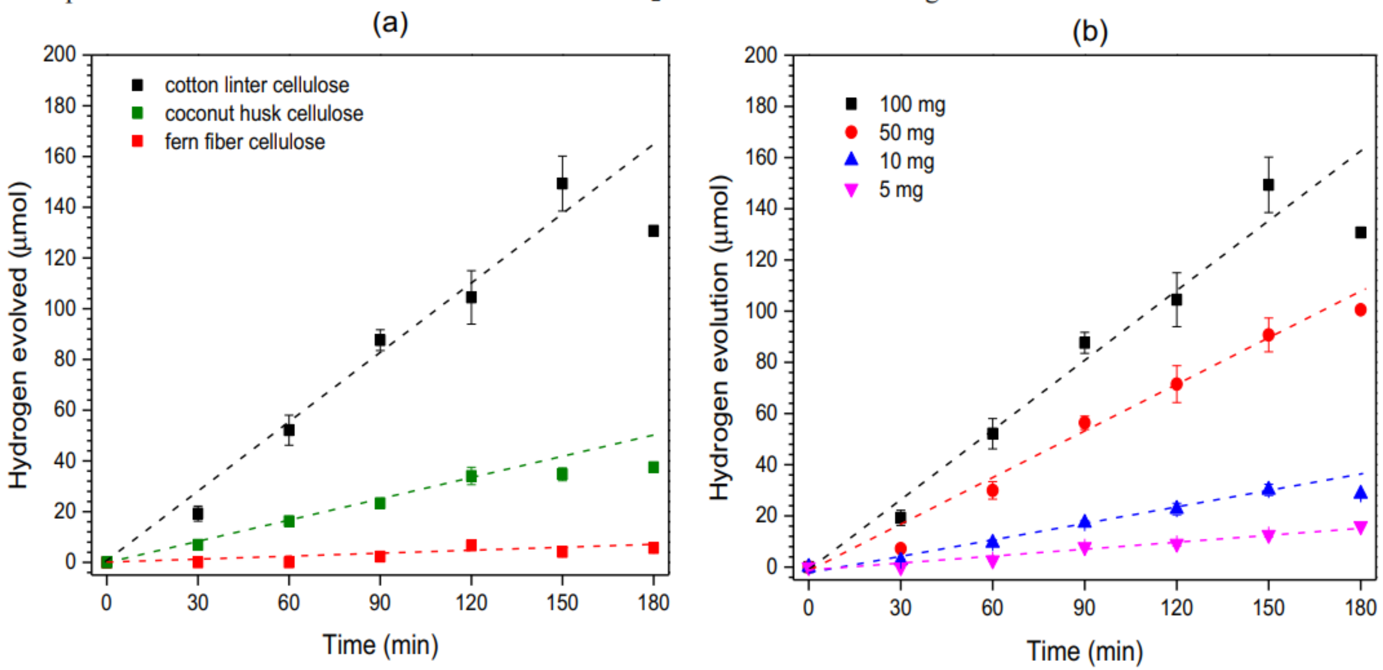
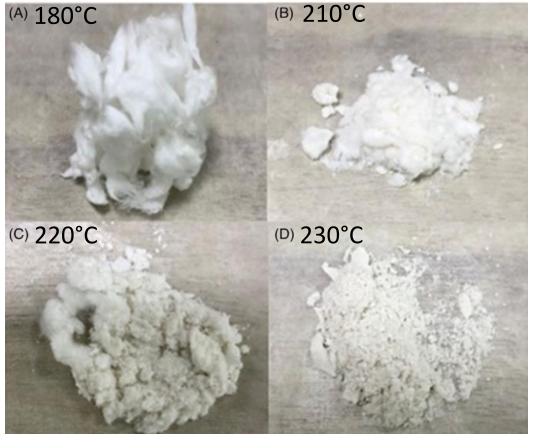
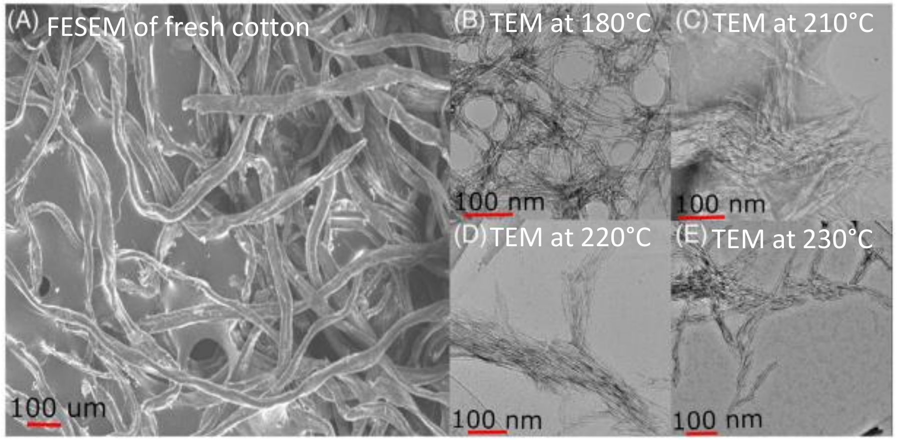


Fig. 8 (a) H_2 production from photodecomposition of cellulose from cotton linter, coconut husk, and fern fiber using 0.3% Pd/TiO_2. (b) H_2 production from photodecomposition of cellulose at different concentrations as a function of time over 0.3% Pd/TiO_2

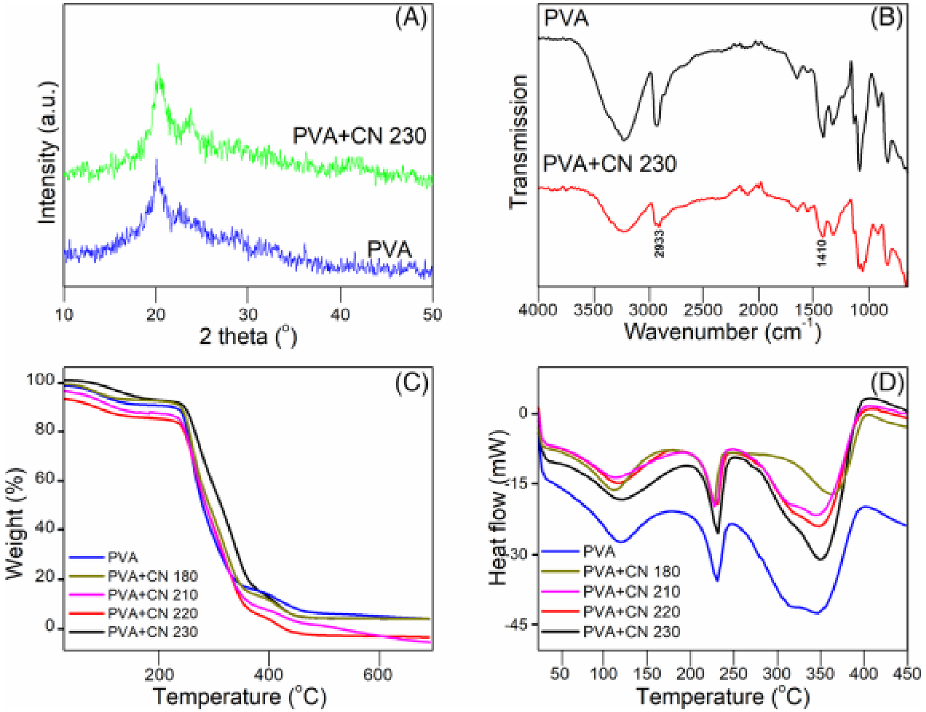
Subcritical Water Hydrolysis of Cotton Fibers to Nanocellulose for Producing Poly(vinyl alcohol)/Cellulose Biocomposite

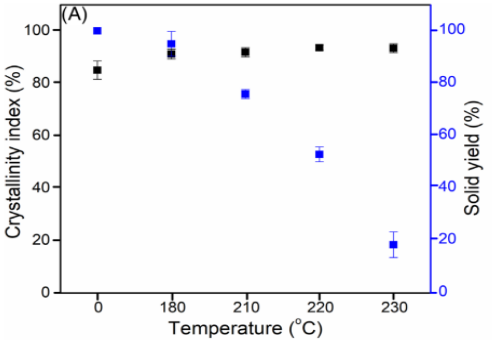


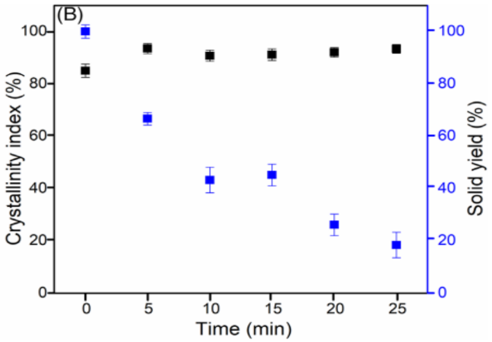


Extracted from HT treatment at 10MPa for 25min

Prepared PVA–cellulose mixture







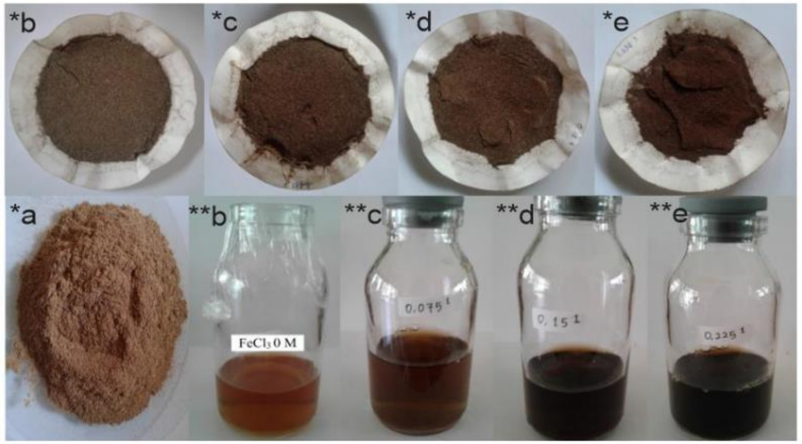
Cotton extracted @230C is used to prepared PVA-cellulose mixture

Samples	PVA	PVA/CN 180	PVA/CN 210	PVA/CN 220	PVA/CN 230
Tensile strength [MPa]	0.14 ± 0.10	0.11 ± 0.02	0.14 ± 0.03	2.70 ± 0.93	0.41 ± 0.24
Elongation at break [%]	10.03 ± 0.12	8.60 ± 0.98	7.68 ± 2.21	14.35 ± 0.64	26.23 ± 4.6
T_{melt} [°C]	230	231	231	233	231
T_{onset} [°C] (decomposition)	249	297	258	258	258

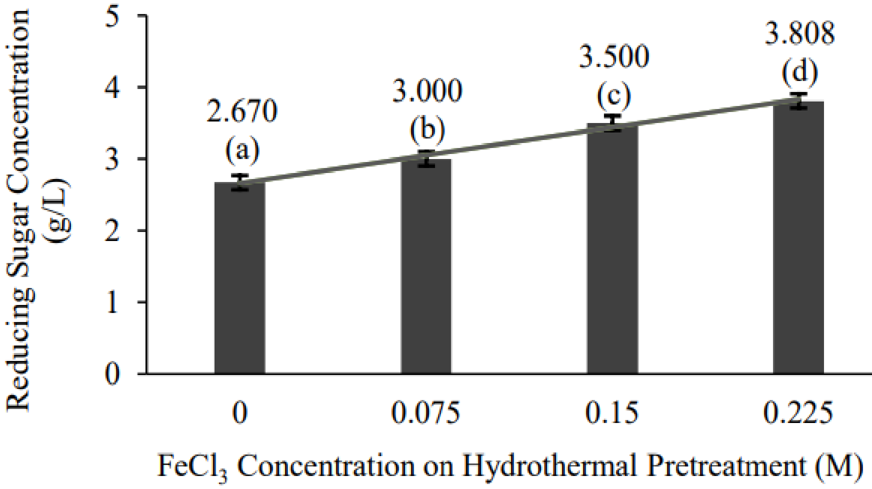
CN, cellulose nanofiber; PVA, poly(vinyl alcohol).

Husnina et al. 2023

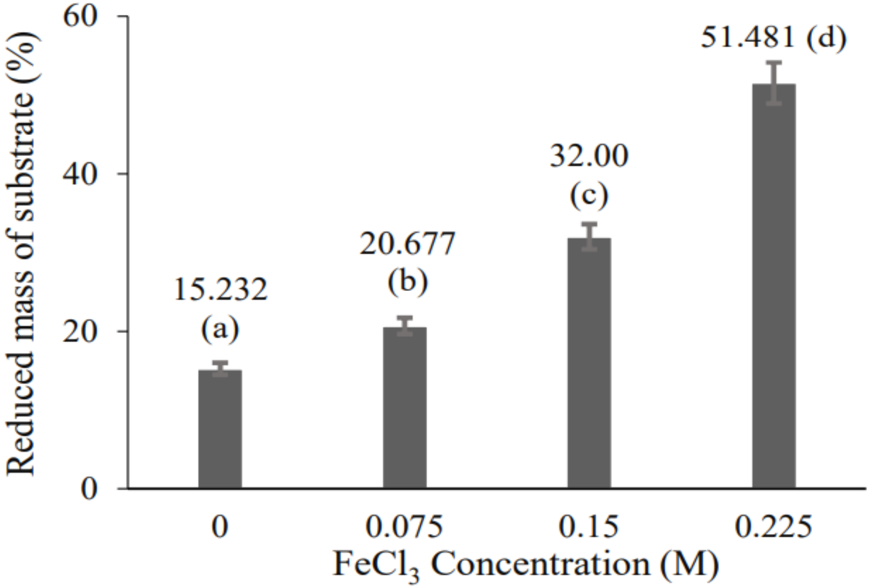
Effect of FeCl3 Concentration on HT Pretreatment of Oil Palm Fronds to Enhance Reducing Sugar Production



The color of the substrate (*) and filtrate (**).
(a) untreated sample of OPF biomass
(b) without the addition of FeCl3;
(c) FeCl3 concentration of 0.075 M;
(d) FeCl3 concentration of 0.150 M;
(e) FeCl3 concentration of 0.225 M.



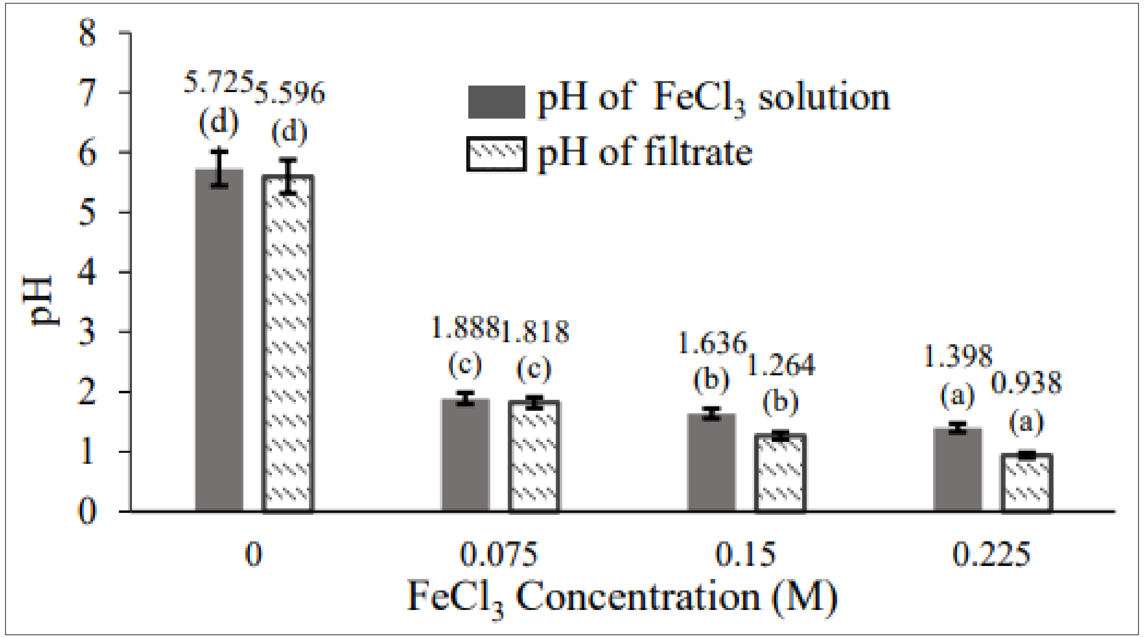
The correlation between reducing sugar concentration and FeCl3 concentration



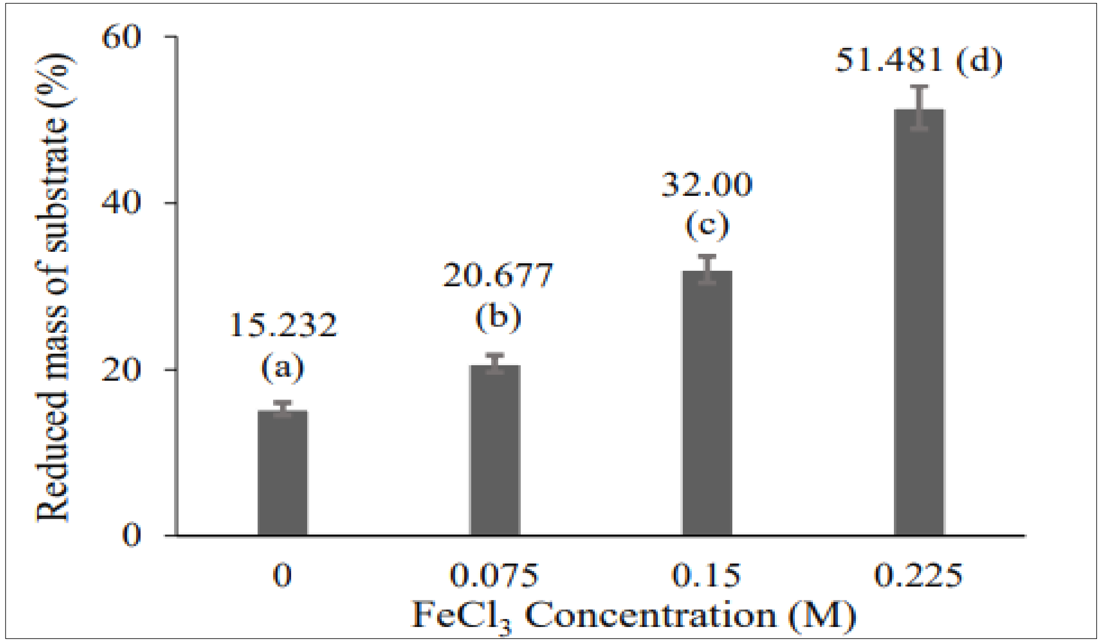
The effect of FeCl3 concentration (M) on a reduced mass of substrate.

Norwahdah et al, 2020

Effect of FeCl3 Concentration on HT Pretreatment of Oil Palm Fronds to Enhance Reducing Sugar Production



Effect of FeCl3 concentration (M) on a the pH of the filtrate

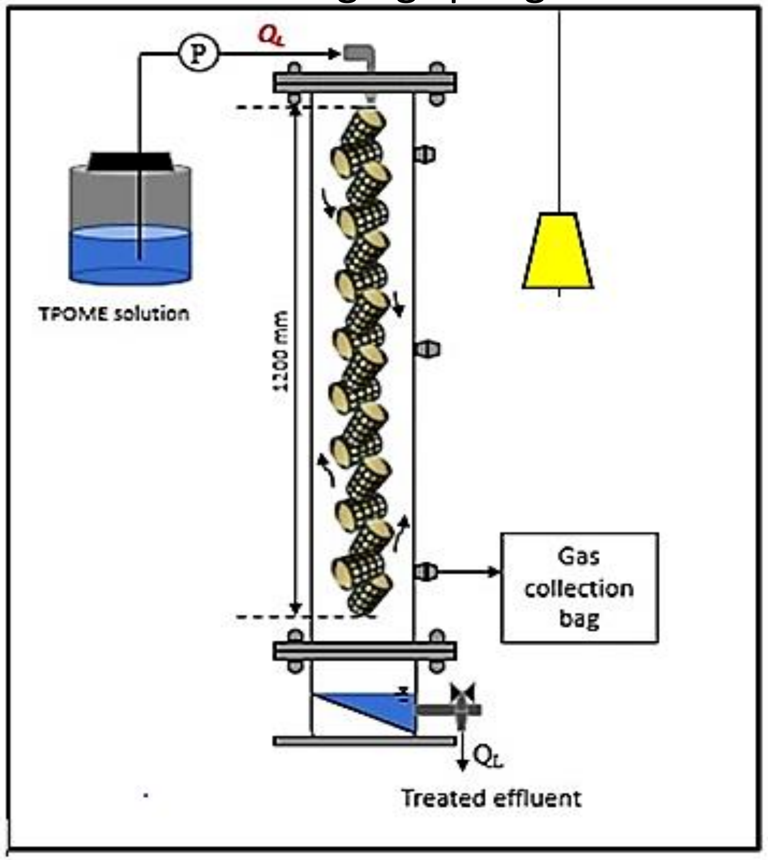


Effect of FeCl3 concentration (M) on a reduced mass of substrate

Norwahdah et al, 2020

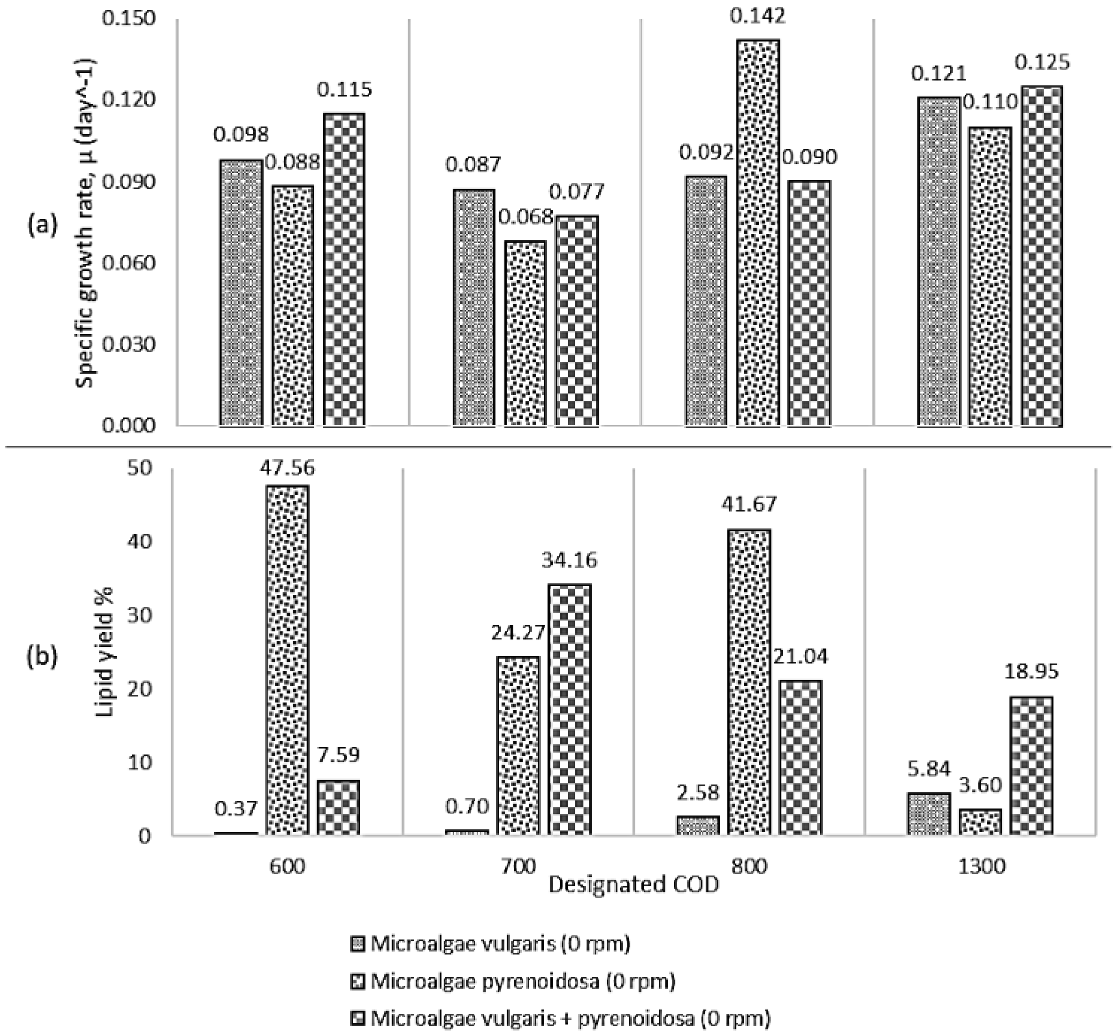
Biotransformation of POME to Biofuel by Immobilized Microalgae in a DHS Reactor

Down-flow hanging sponge reactor



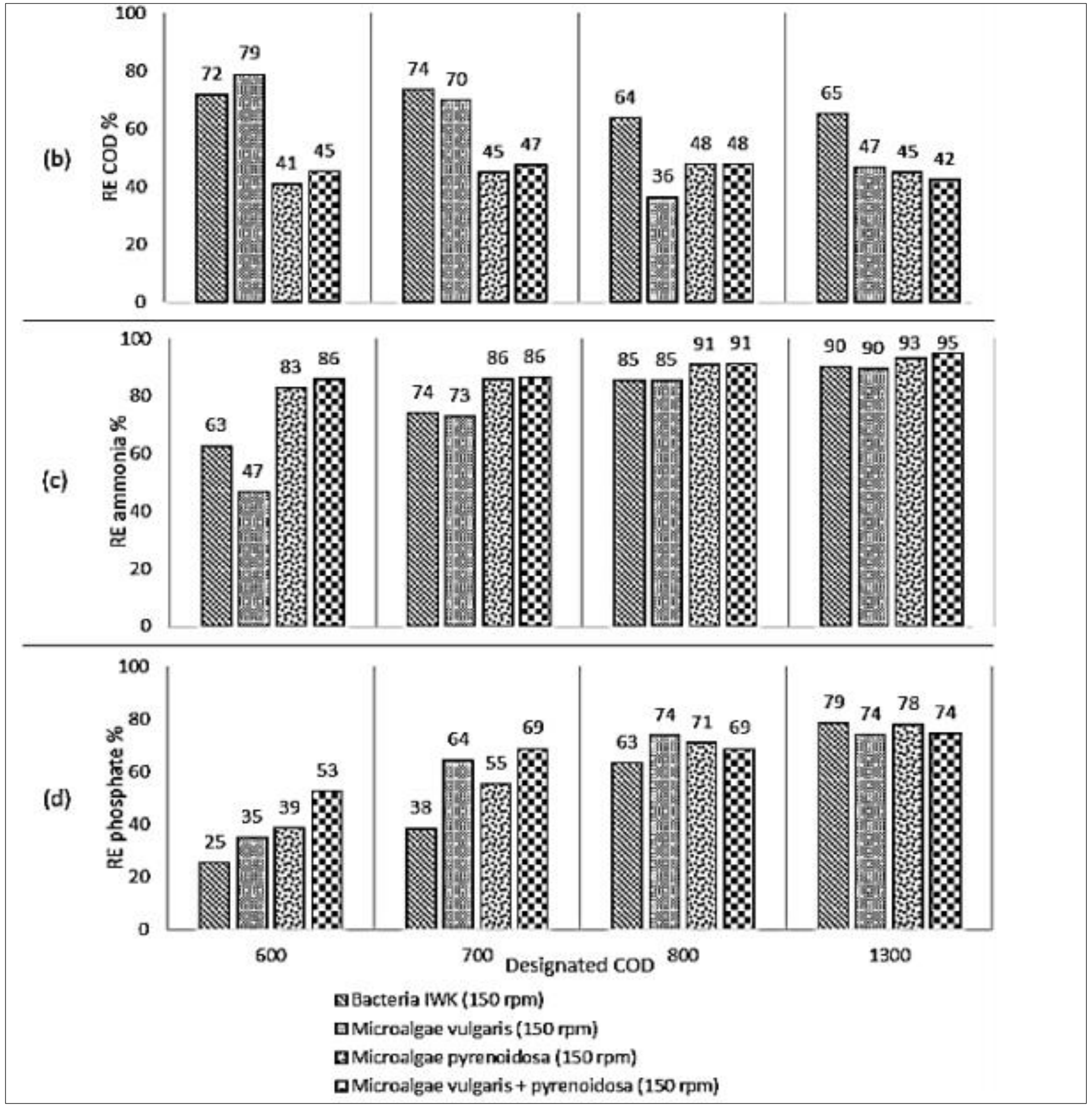
Frame sponge provides

- **High retention time**
- **Large void volume**
- **High surface area**
- **Reusable**

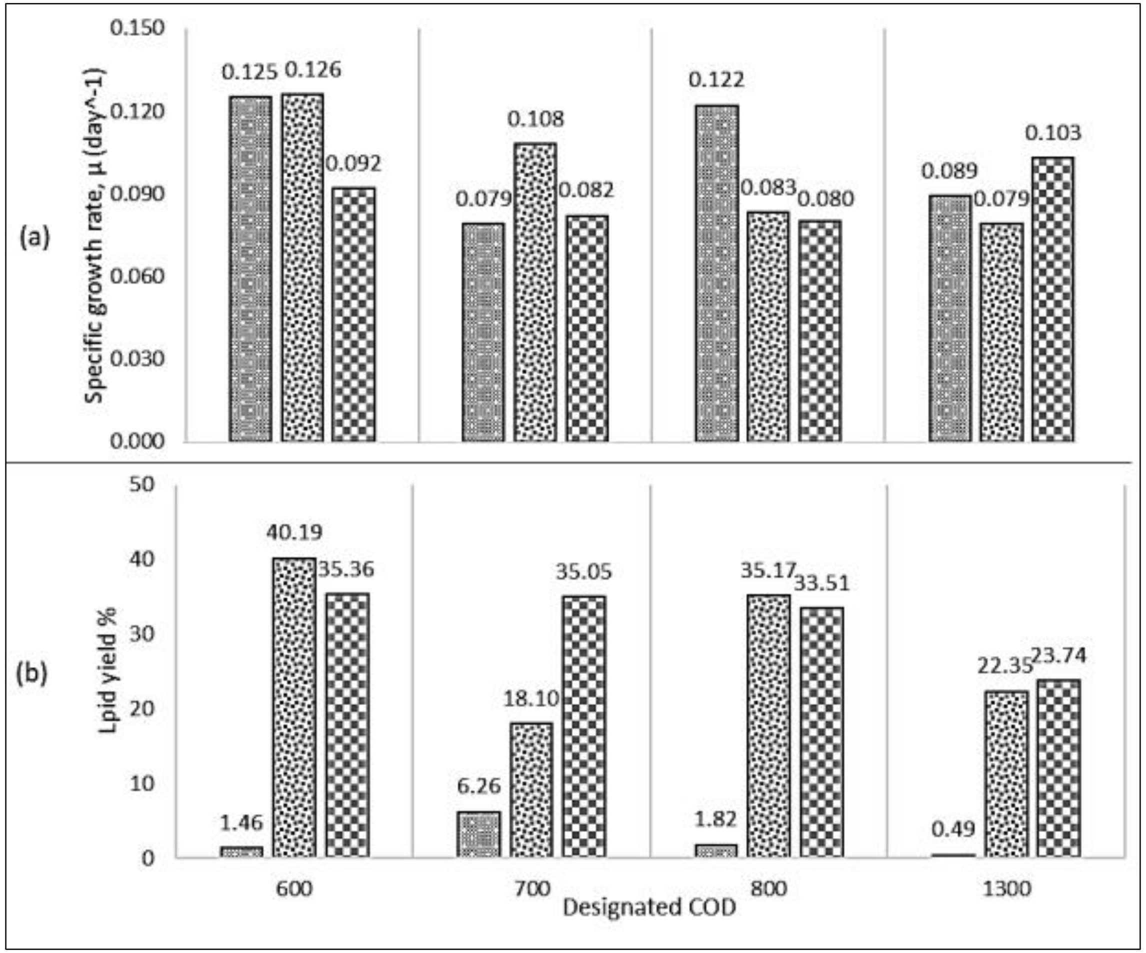


Microalgae productivity at 0 rpm agitation a) Specific growth (b) lipid for microalgae yield

Azni et al. 2022



POME pollutants removal efficiency percentage with designated COD conc. At 150rpm agitation (b) COD (c) ammonia (d) phosphorus



Microalgae productivity at 150 rpm agitation a) Specific growth (b) lipid for microalgae yield

Azni et al. 2022

Thank you for your attention

Email: rosnah.abdullah@ubd.edu.bn