

Turning Biomass into Biochar for a Cleaner Energy and Water Future

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W https://www.scopus.com/authid/detail.uri?authorId=56573167300 (h-index: 34)
Top 2% of scientists in 2023, 2024, 2025, and 2026 (yearly) by Stanford University

From biomass or waste-derived catalysts to engineered carbon materials

WASTE → FUNCTION → CIRCULARITY

Waste biomass

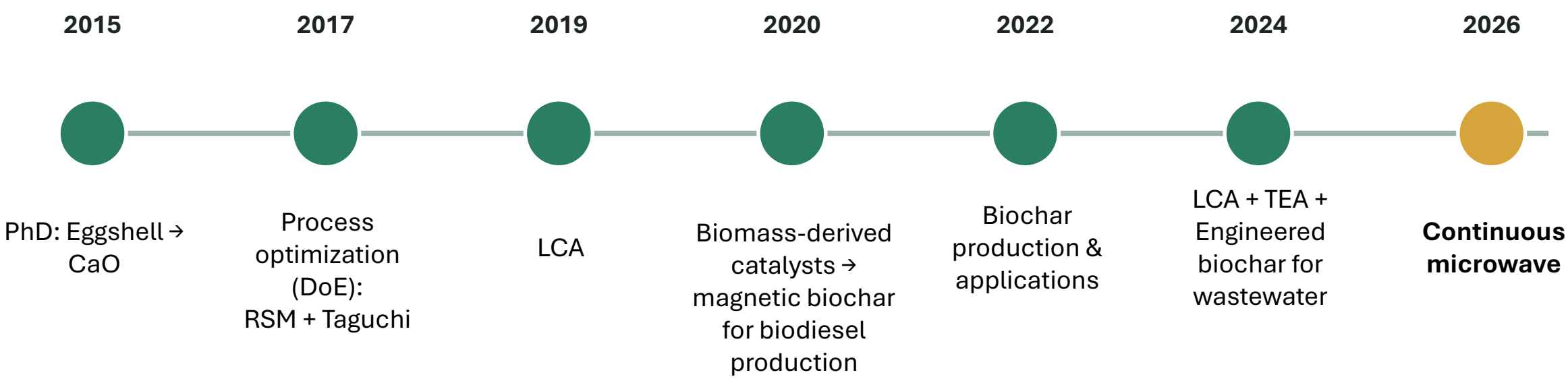
Low-value residues become starting materials rather than end-of-life burdens.

Does it work? Can we afford to make and use it? And is it actually better for the environment?

Energy + water

Performance is evaluated together with LCA, TEA, and reuse.

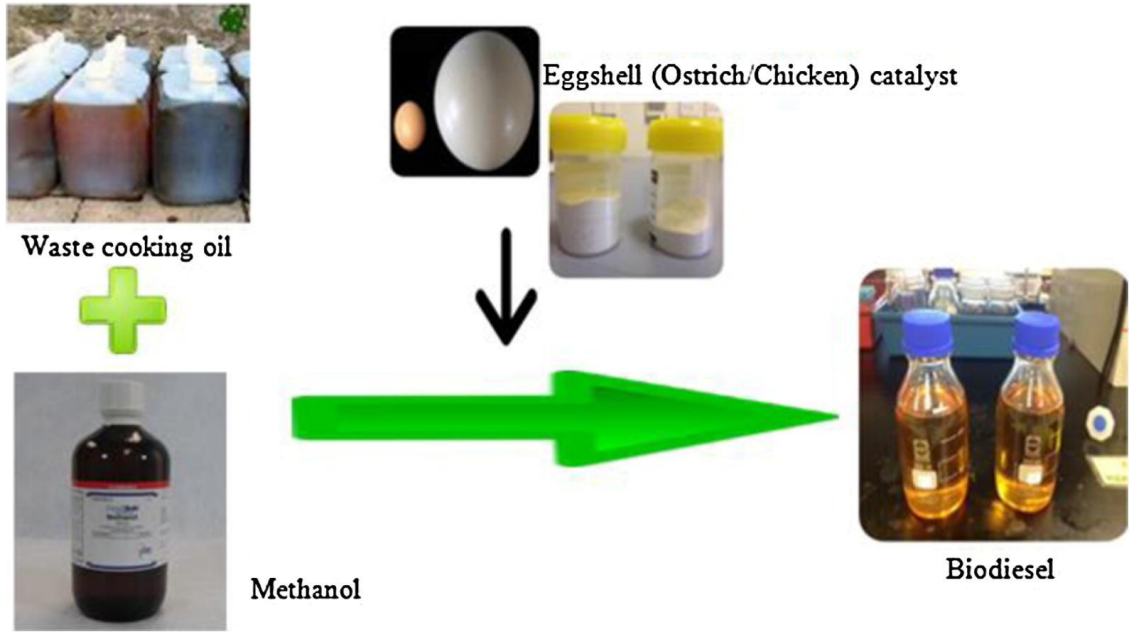
My Research Journey



Waste Ostrich- and Chicken-eggshells as Heterogeneous Base Catalyst for Biodiesel Production from Used Cooking Oil: Catalyst Characterization and Biodiesel Yield Performance

https://doi.org/10.1016/j.apenergy.2015.09.023

Waste eggshell → **Calcination** → **CaO catalyst** → **Biodiesel**



Optimised conditions

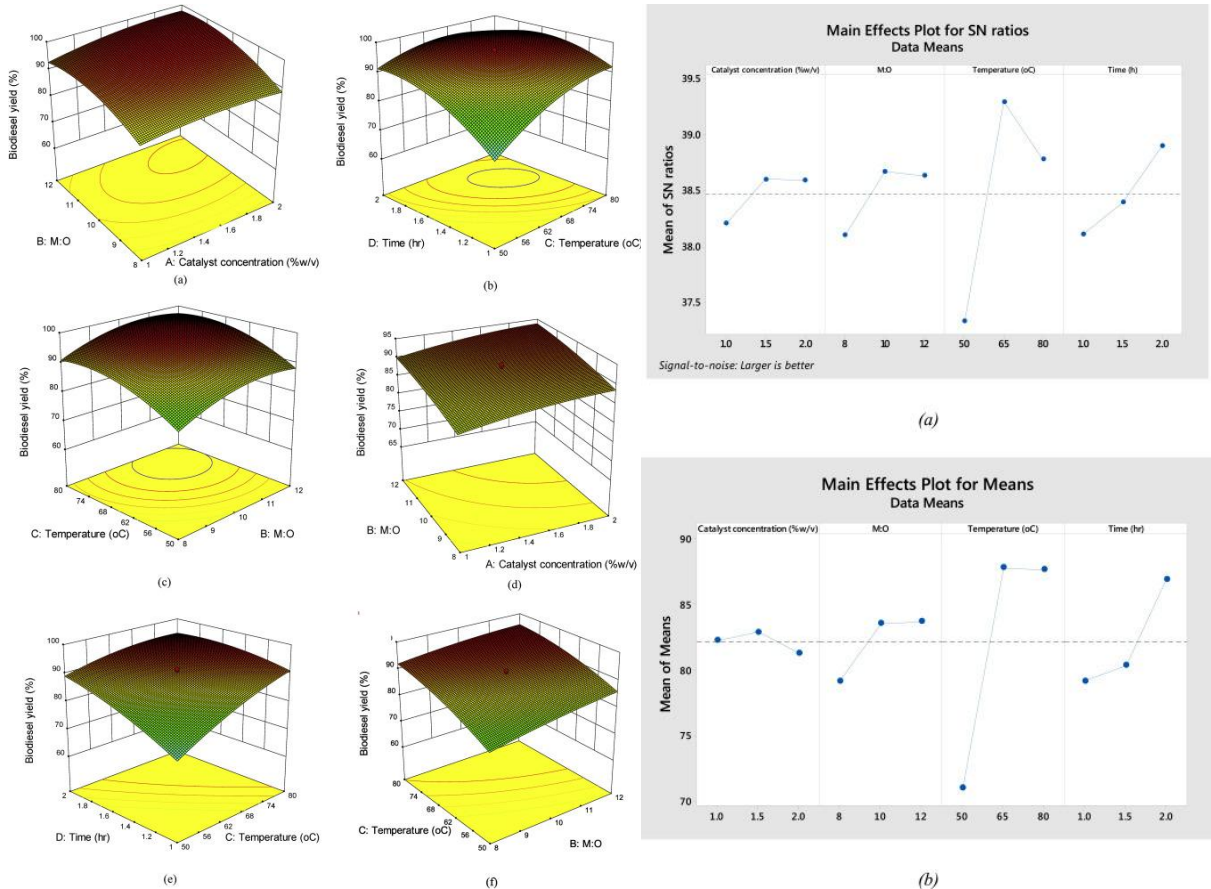
1.5 wt% catalyst
methanol:oil 12:1
65°C
2 h

OSTRICH EGGSHELL
96%
Biodiesel yield

CHICKEN EGGSHELL
94%
Biodiesel yield

Application of RSM And Taguchi Methods for Optimizing The Transesterification of Waste Cooking Oil Catalyzed by Solid Ostrich and Chicken-eggshell Derived CaO

https://doi.org/10.1016/j.renene.2017.07.024



(a)

(b)

Design of Experiment (DoE)

- Response Surface Methodology (RSM)
- Taguchi Method

Optimised conditions

1.5 %w/v catalyst
methanol:oil 10:1
65°C - most influential parameter
2 h

OSTRICH EGGSHELL
~98%
Biodiesel yield

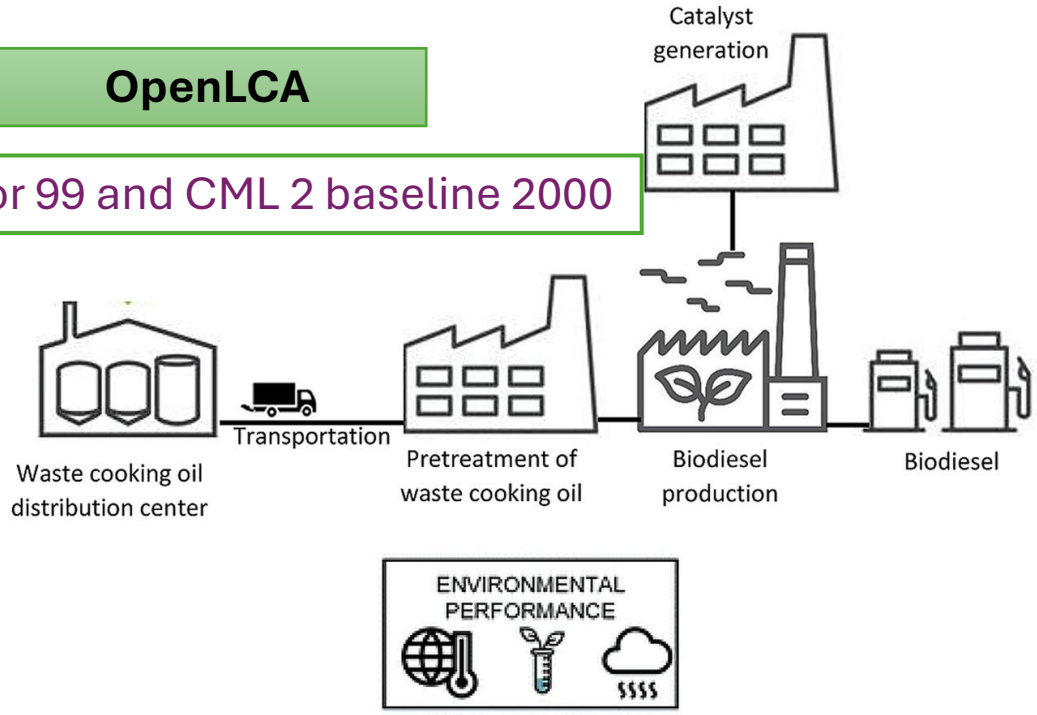
CHICKEN EGGSHELL
~96%
Biodiesel yield

Life Cycle Assessment of Waste Cooking Oil for Biodiesel Production Using Waste Chicken Eggshell Derived CaO as Catalyst via Transesterification

https://doi.org/10.1016/j.bcab.2019.101317

OpenLCA

Eco-indicator 99 and CML 2 baseline 2000



LCA insight

Although both feedstock and catalyst were waste-derived, the transesterification stage carried the largest environmental burden, particularly because of electricity demand.

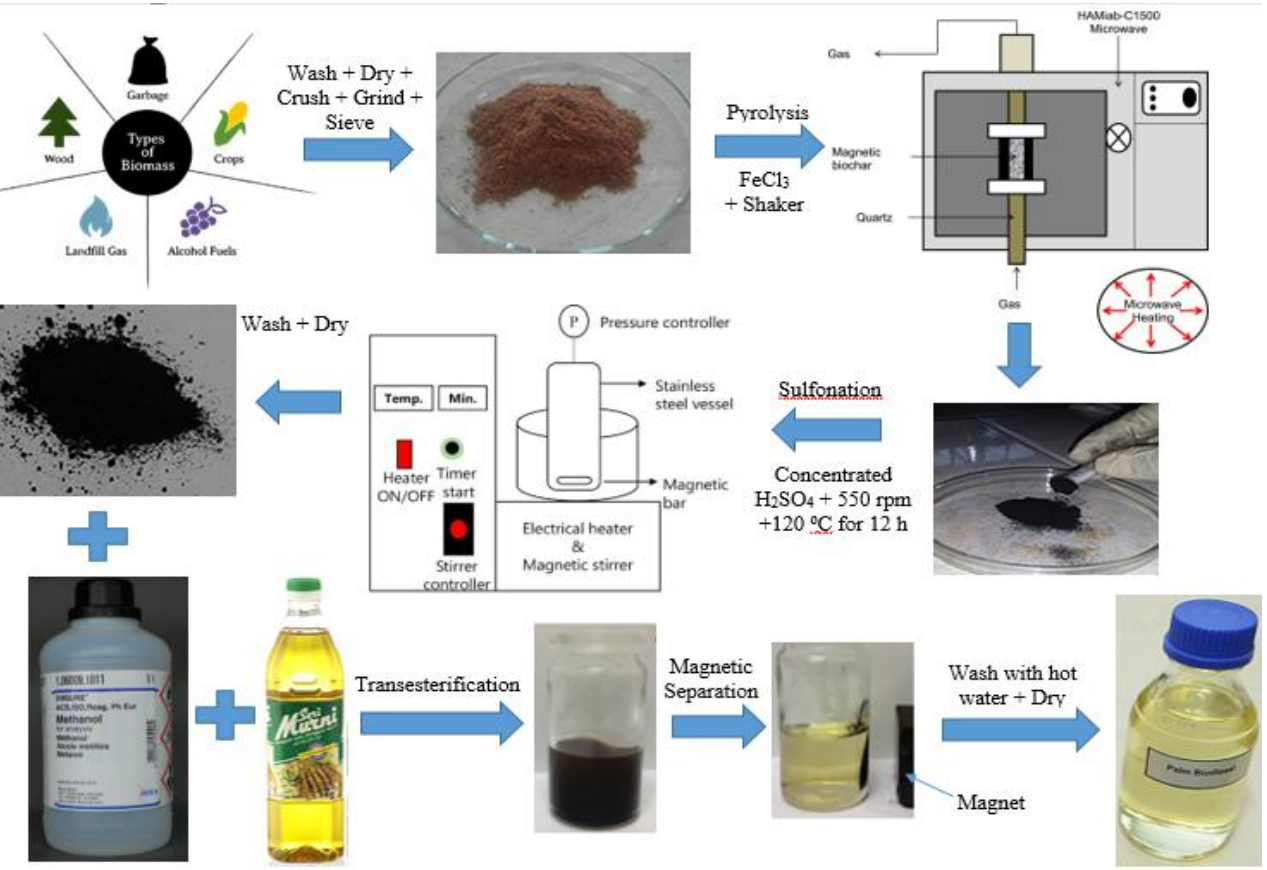
Waste oil → **Pretreatment** → **Transesterification** → **Separation** → **Biodiesel**

HOTSPOT

FRGS grant

Magnetic Biochar Derived from Waste Palm Kernel Shell for Biodiesel Production via Sulfonation

https://doi.org/10.1016/j.wasman.2020.09.016



Response Surface Methodology (RSM)



Optimised conditions

3.66 wt% catalyst
methanol:oil 13:1
65°C
102 minutes

90.2%

Biodiesel yield

Biodiesel Production Catalysed by Magnetic Palm Kernel Shell-Potassium Hydroxide https://doi.org/10.1051/matecconf/202337701012



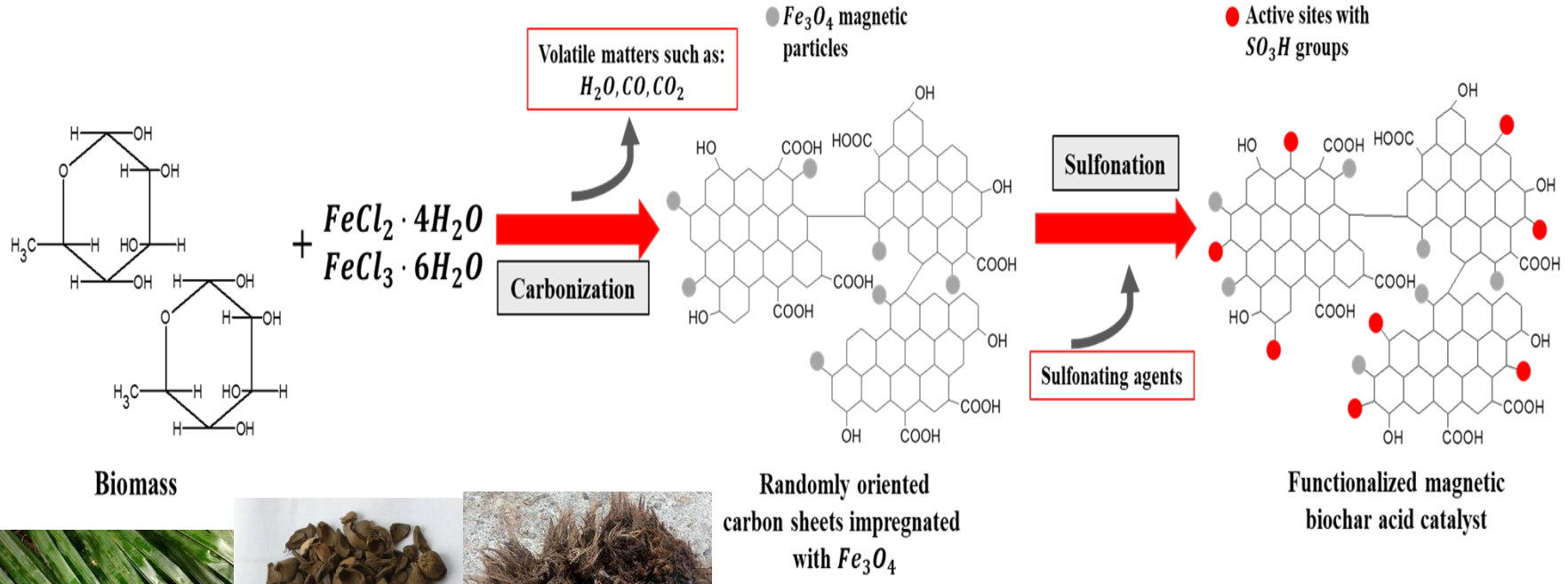


- **Biodiesel** was produced from palm oil through transesterification using a **magnetic palm kernel shell–KOH heterogeneous catalyst**.
- The developed magnetic catalyst exhibited a BET **surface area of 47.72 m^2/g**, supporting its application in biodiesel production.
- A maximum biodiesel yield of **95.78%** was achieved at 55°C with a reaction time of 2 hours.

Transesterification of Used Cooking Oil by Palm Lignocellulosic Biomass Magnetic Biochar Catalyst: Optimization and Kinetic Analysis https://doi.org/10.1016/j.renene.2024.120750

Response Surface Methodology (RSM)

Synthesis pathway of functionalized magnetic biochar acid catalyst





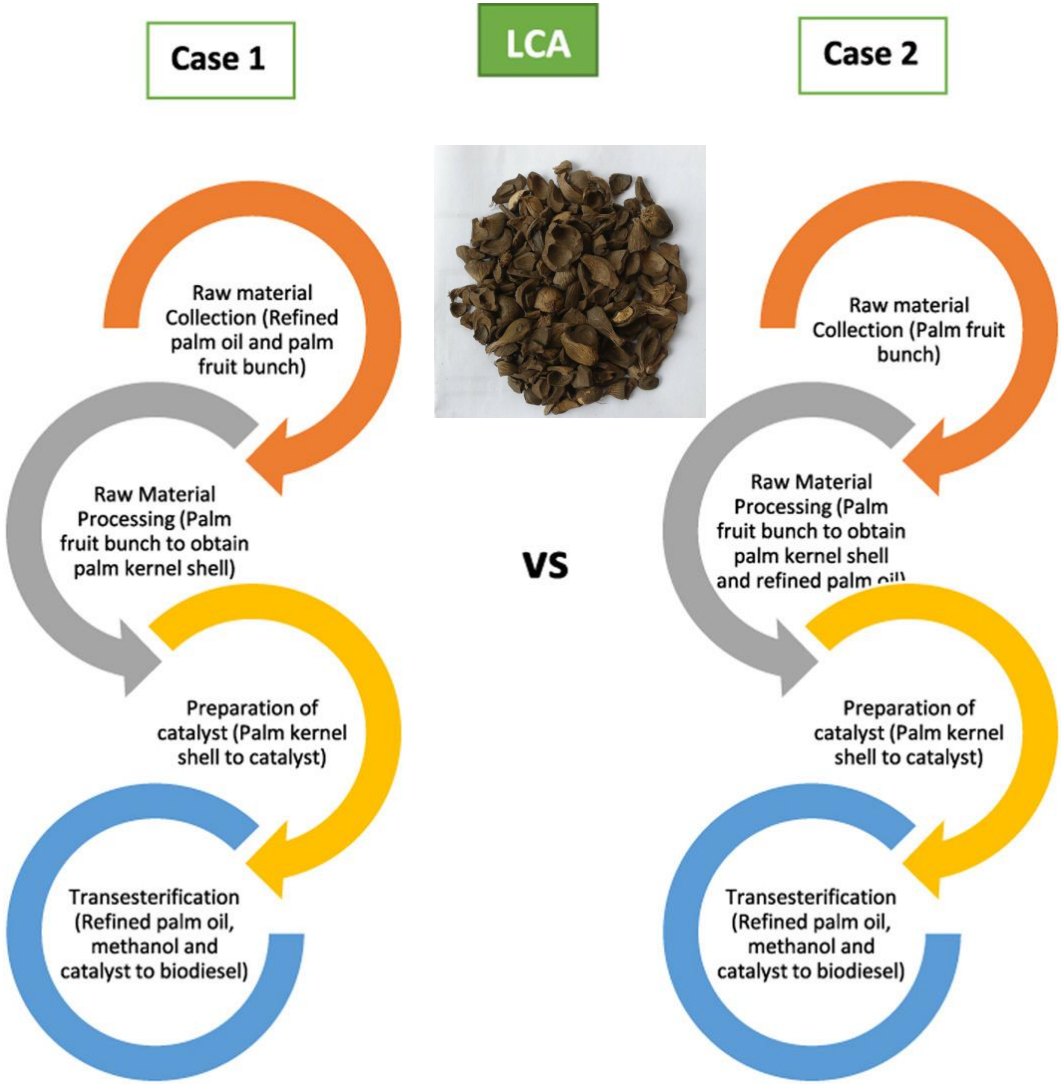
Optimised conditions

EFB
10.12 wt% catalyst
methanol:oil 28:1
70°C

91.5%
Biodiesel yield

Pseudo-irreversible first-order kinetic with an activation energy of 29.20 kJ mol^{-1}

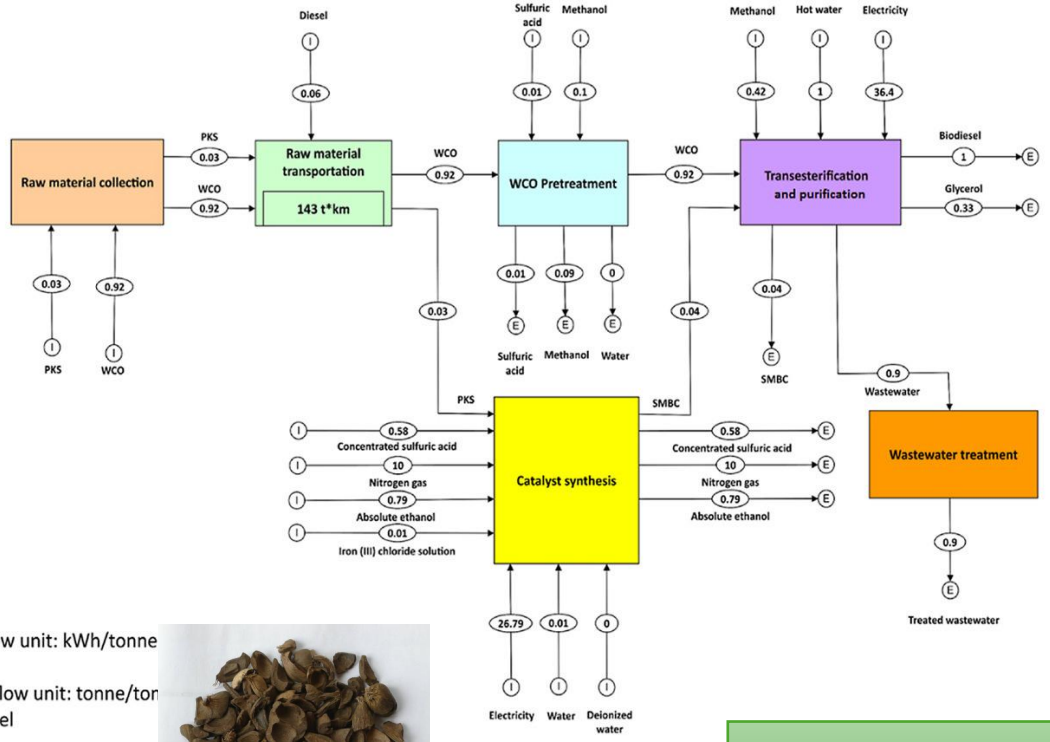
Life Cycle Assessment of Biodiesel Production by Using Impregnated Magnetic Biochar Derived from Waste Palm Kernel Shell https://doi.org/10.1016/j.envres.2022.114149



SimaPro

- **Waste palm kernel shell-derived magnetic biochar** offers a reusable alternative to conventional catalysts for biodiesel production.
- Using refined palm oil (Case 1) **reduced environmental impacts by 64%**, with a total impact of 664 Pt, compared to 1,830 Pt for Case 2.
- **Transesterification** was the **main environmental hotspot**, with marine aquatic ecotoxicity reaching 1.00×10^6 kg 1,4-DB eq/tonne biodiesel and cumulative endpoint damage of 461 Pt.

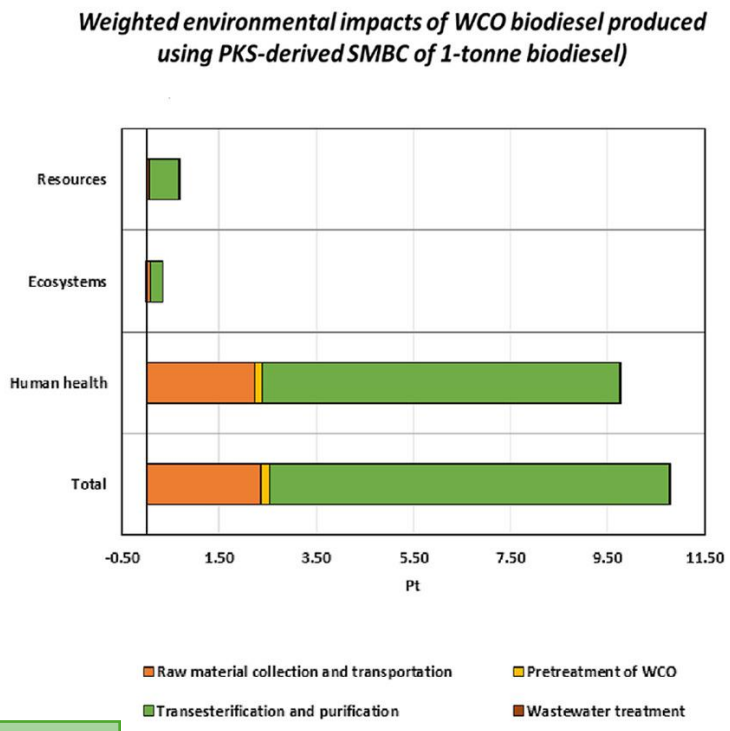
Assessing Biodiesel Production Using Palm Kernel Shell-derived Sulfonated Magnetic Biochar from the Life Cycle Assessment Perspective https://doi.org/10.1016/j.energy.2023.128758



Energy flow unit: kWh/tonne biodiesel
Material flow unit: tonne/ton of biodiesel

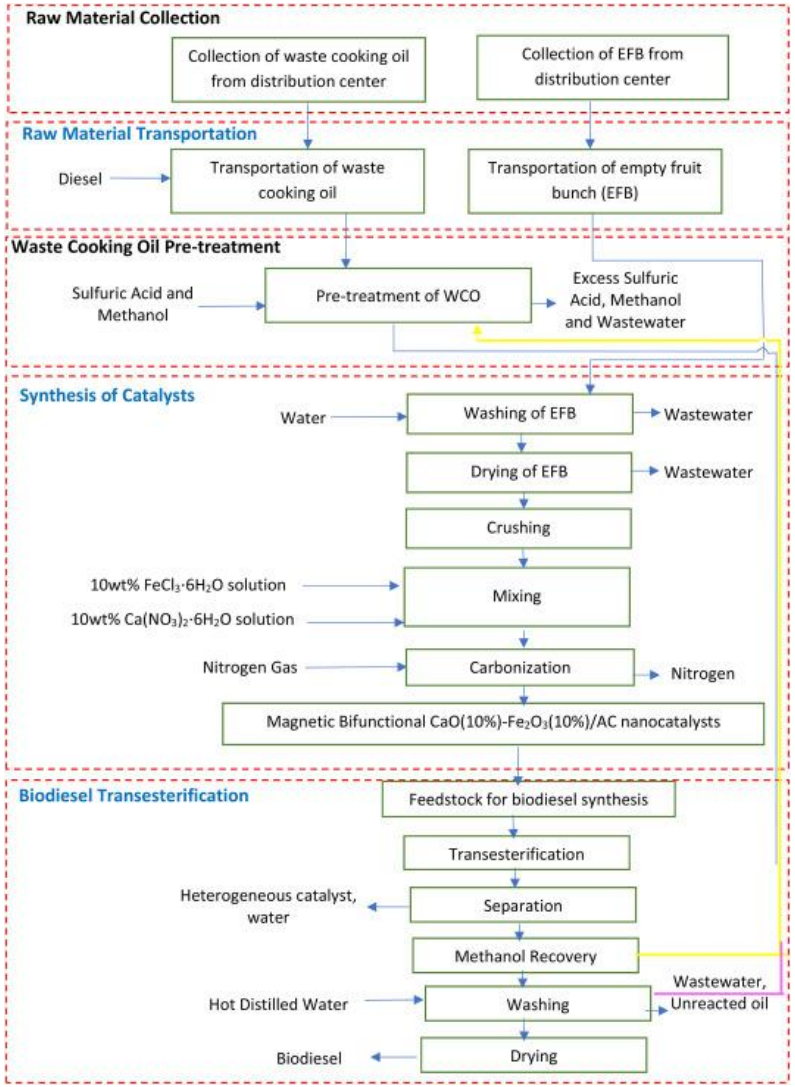


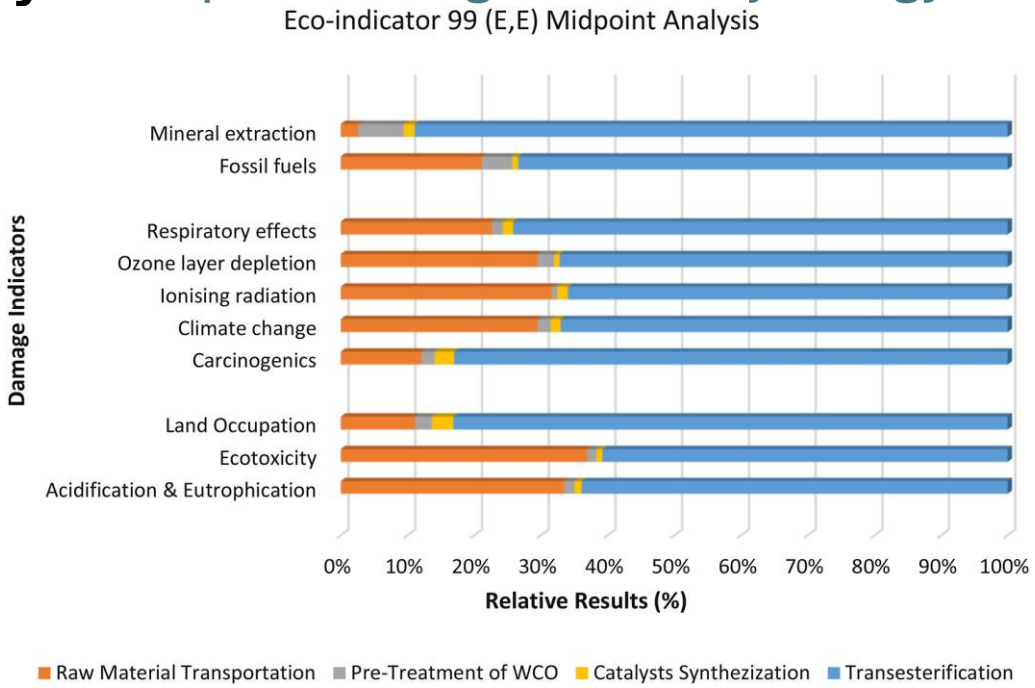
SimaPro



- Waste-oil transesterification contributes **79% of biodiesel carbon emissions**.
- It accounts for about **90% of resource damage**.
- Biodiesel reduces total impacts by **55% compared with diesel**.
- Replacing palm oil with waste oil cuts impacts by **89%**.

A Life Cycle Assessment of Biodiesel from Waste Cooking Oil Using Bifunctional Magnetic Nanocatalyst https://doi.org/10.1016/j.energy.2025.137029





OpenLCA



- **WCO + EFB-derived Ca–Fe nanocatalyst** enabled high-yield biodiesel production from waste resources.
- **Transesterification was the main LCA hotspot**, with fossil-fuel depletion reaching **39.029 Pt per 1000 kg biodiesel**.
- Using **WCO and waste-derived catalysts** improves sustainability, while solar power can lower fossil use but may increase some production-related emissions.

Filed Patents, Copyrights, and Research Awards from the Magnetic Biochar Project

Tan Yie Hua, N.M. Mubarak, 2020, Magnetic biochar Catalyst, PI2020007233
Tan Yie Hua, 2019, Novel Column for Biodiesel Production, PI2019007916

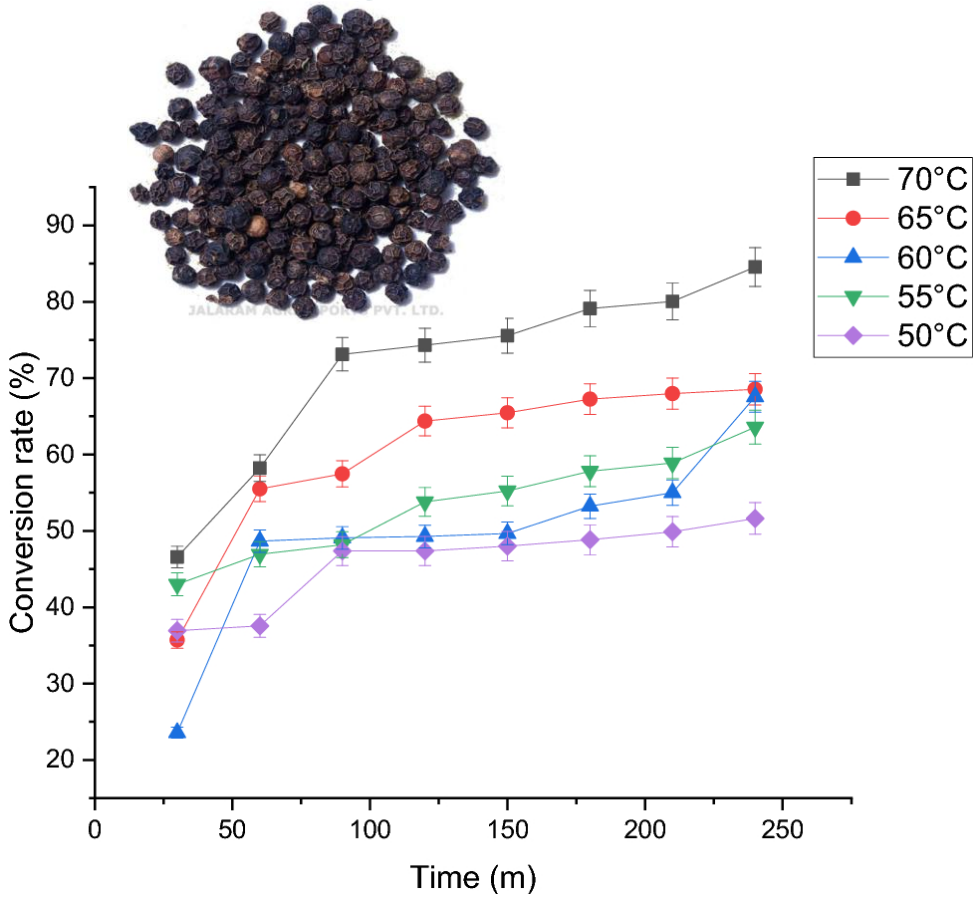
Tan Yie Hua, 2023, Biodiesel Production, LY2023Q04170
Tan Yie Hua, Jibrail Kansedo, Mohd Nurfidaus Bin Mohiddin, 2023, Biodiesel Reaction Mechanism, LY2023Q04174
Tan Yie Hua, 2020, Biodiesel Synthesis using Magnetic Palm Kernel Shell Biochar, LY2020007390

Gold Award – Virtual International Innovation for Climate & Ecosystem Resilience 2026 (VIICER2026)
Bronze Medal in the Local Category 2 of CIPTA 2025 (Creative, Innovative Product and Technological Advancement) 2025
Gold Award – Malaysia Technology Expo (MTE) 2023
Gold Award – Innovation and Technology Expo InTEX22 (2022)
Silver Award – International Conference and Exposition on Inventions by Institutions of Higher Learning (PECIPTA) (2022)
Best Project Award – 3rd Bionanotechnology Research Seminar and Conference (BioNanoSem 2022)

1 PhD student graduated and now as a lecturer at UNIMAS

Kinetic and Thermodynamic Studies of Transesterification Catalysed by Black Pepper Seed-Potassium Hydroxide Catalyst

https://doi.org/10.1007/s11244-023-01891-8



- **Black pepper seed–KOH catalyst** was used for palm oil transesterification at 50–70°C, with 5 wt% catalyst and a 6:1 methanol-to-oil ratio.
- The reaction followed **pseudo-irreversible first-order kinetics**, with an activation energy of 61.52 kJ/mol and a pre-exponential factor of 1.14×10^{7} min^{-1}.
- **Positive enthalpy (ΔH = 58.75 kJ/mol) and Gibbs free energy (ΔG = 86.22–87.92 kJ/mol)** indicated an endothermic and non-spontaneous reaction under the studied conditions.

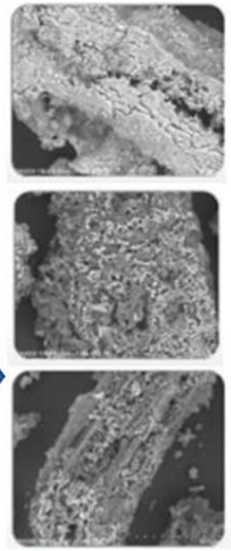
Techno-economical and Energy Analysis of Sunflower Oil Biodiesel Synthesis Assisted with Waste Ginger Leaves Derived Catalysts

https://doi.org/10.1016/j.renene.2020.12.100





Fresh Ginger leaves

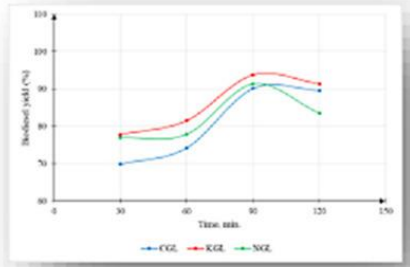


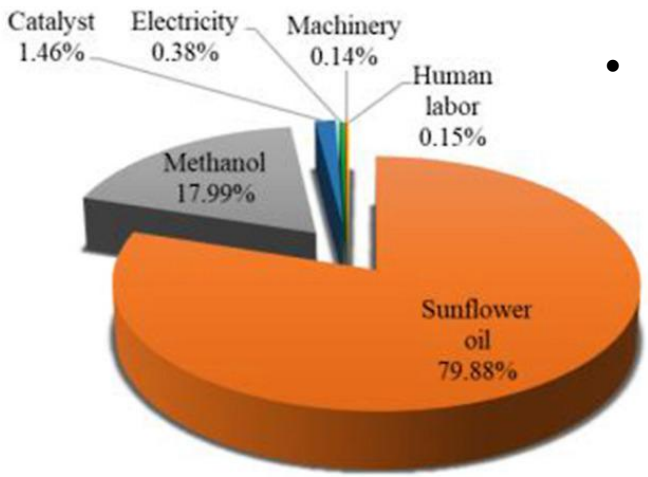
Preparation of Catalyst

1. Calcination (CGL)
2. KOH activation (KGL)
3. NaOH activation (NGL)



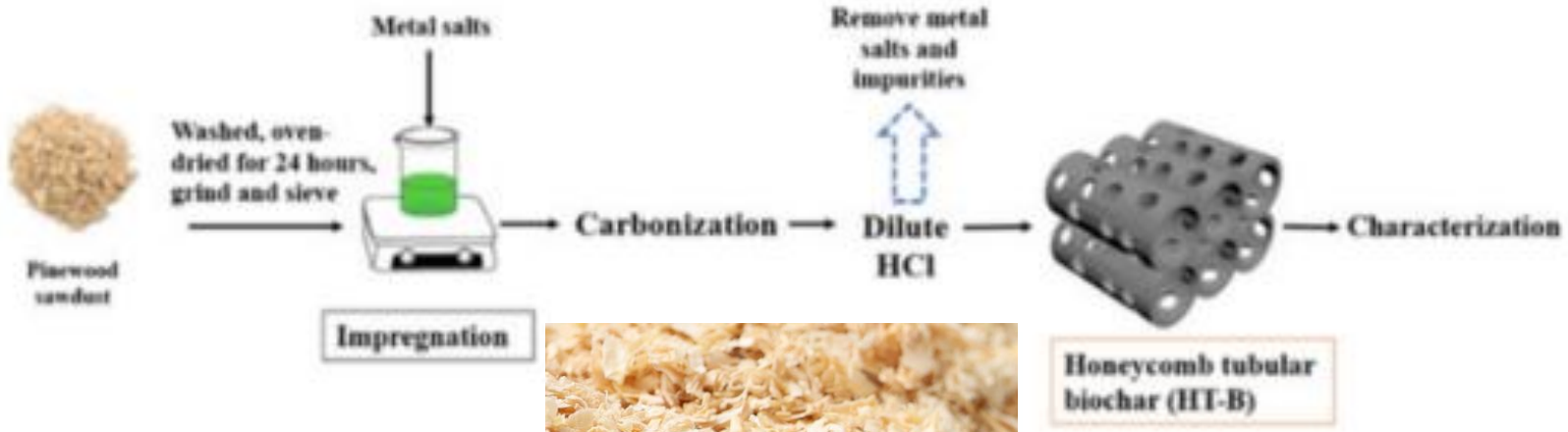
Biodiesel production





- **Novel ginger leave-based** catalysts CGL, KGL and NGL.
- Yield (**93.83%**) with KGL under optimum conditions: 90 min, 6:1, methanol to oil and 1.6 wt % catalyst.
- Profit cost ratios 1.434 for KGL, 1.420 for NGL and 1.397 for CGL catalyst.

Characterization of Valorized Pinewood Sawdust to Engineered Activated Biochar https://doi.org/10.1007/978-981-99-1695-5_34





- **Pinewood sawdust (PWS)** was converted into engineered biochar through $ZnCl_2$ activation and carbonization at 800°C for 6 hours.
- PWS treated with 1.0 M $ZnCl_2$ exhibited a **stable honeycomb-like tubular structure** with **larger porosity**.
- Hydroxyl and carboxyl functional groups enhanced the potential of PWS-derived biochar as a **sustainable biosorbent** for environmental remediation.

Water treatment using silver-iron-modified biochar for enhanced disinfection and sustainability doi: 10.36922/EER025480081



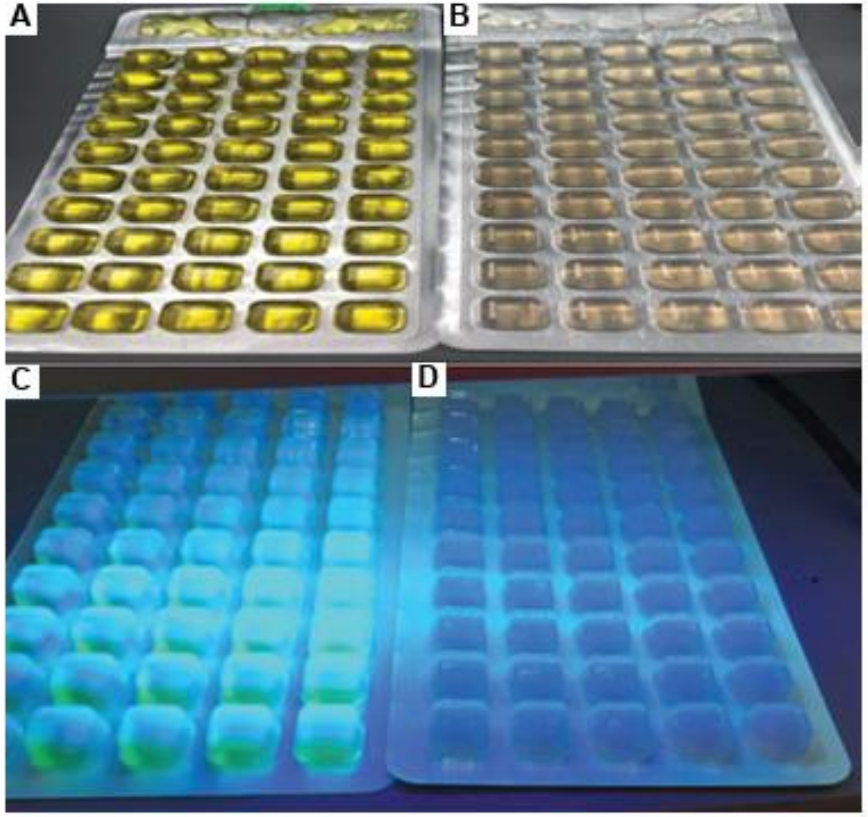


Figure 2. The differences between untreated pond water and treated pond water. Untreated pond water under (A) ambient light and (C) ultraviolet light. Treated pond water under (B) ambient light and (D) ultraviolet light.

- Pathogenic microorganisms threaten water safety, highlighting the need for sustainable and cost-effective disinfection technologies.
- **Palm kernel shell biochar** was used to form **silver-iron (Ag-Fe)-modified biochar** as a photocatalyst.
- Ag-Fe-modified biochar containing **4.3 wt% Ag and 30.0 wt% Fe** demonstrated bacterial inactivation under visible light through combined antibacterial and photocatalytic effects.

Synthesis and Characterization of Pyrolyzed and H_3PO_4-Activated Maize Cob for Aspirin Removal

https://doi.org/10.1016/j.nxmate.2026.103380

01 MAIZE COB PREPARATION



- Wash and reduce size
- Oven-dry: 80 °C, 48 h
- Sieve to 5 mm

Maize cob waste

02 PYROLYSIS → Pyr-MC



- 460 °C for 2 h
- Argon: 50 mL/min
- Cool, grind; sieve 1 mm

Tube furnace

03 H_3PO_4 ACTIVATION → MCAC



- 30 g Pyr-MC + 0.5 M H_3PO_4
- Stir to form a paste
- Heat: 550 °C, 30 min
- Wash to neutral pH
- Dry: 105 °C, 2 h

Acid-treated carbon

ASPIRIN ADSORPTION PERFORMANCE

Aspirin removal efficiency

Dose: 0.06 g | optimum pH: Pyr-MC 3, MCAC 4

Pyr-MC	82.3%
MCAC	56.0%

Adsorption capacity

Pyr-MC	15.0 mg/g
MCAC	4.6 mg/g

MATERIAL CHARACTERIZATION

Measured property	Pyr-MC	MCAC
BET surface area (m^2/g)	111.36	105.08
Pore volume (cm^3/g)	0.11	0.10
Average pore diameter (nm)	4.03	4.61
Freundlich fit (R^2)	0.96	0.63

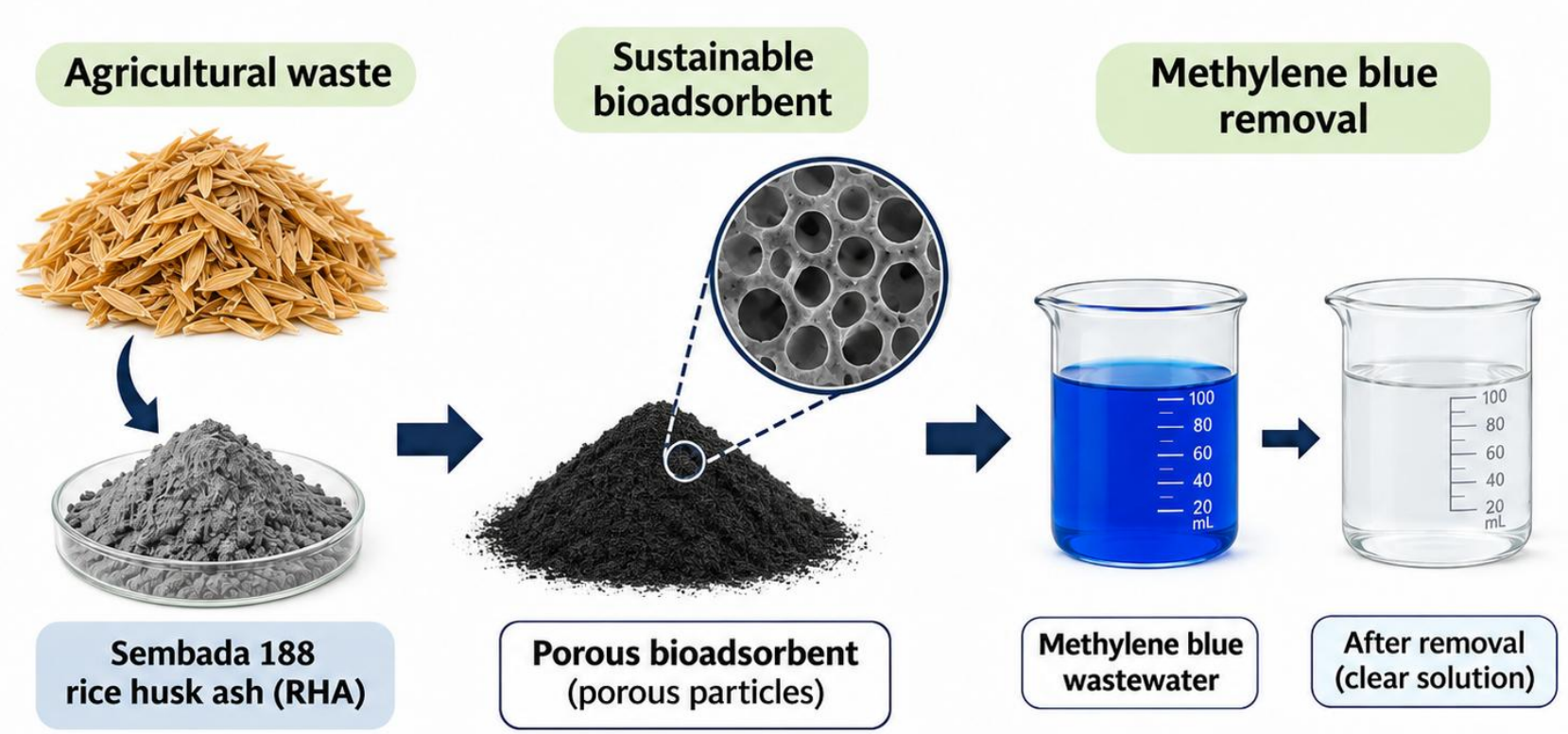
FESEM: developed pores • FTIR: O-H, C=C, C-O-C groups

MCAC had larger pores, but poorer aspirin adsorption.

- Pyr-MC achieved **82.3%** aspirin removal and 15.0 mg/g adsorption capacity, outperforming MCAC (56%; 4.6 mg/g).
- Pyr-MC showed a **higher surface area** (111.36 m^2/g) and strong Freundlich fit (R^2 = 0.96).
- Pyr-MC offers a **low-cost, effective adsorbent** without chemical activation.

Valorization of *Sembada 188* Rice Husk as a Sustainable Bioadsorbent for Methylene Blue Removal

https://doi.org/10.1049/icp.2026.1014



- ***Sembada 188* RHA** achieved **95% MB removal** at pH 10 within 60 minutes using 500 mg adsorbent.
- RHA demonstrated an **adsorption capacity of 54.3 mg/g** and a zeta potential of −49 mV, promoting electrostatic attraction.
- RHA provides a **low-cost, sustainable, and eco-friendly** alternative to commercial adsorbents for dye-contaminated wastewater.

Conclusions

- **Waste Valorisation:** Agricultural and other waste materials, including palm kernel shells, empty fruit bunches, eggshells, and rice husks, can be transformed into valuable catalysts, biochar, and adsorbents.
- **Renewable Energy:** Waste-derived catalysts achieved biodiesel yields of up to approximately 98%, demonstrating their potential for renewable fuel production.
- **Water Treatment:** Biomass-derived materials achieved 82.3% aspirin removal using maize cob and 95% methylene blue removal using rice husk ash. Ag–Fe-modified biochar also demonstrated antimicrobial activity under visible light.
- **Sustainability and Future Direction:** Life cycle and techno-economic assessments are essential to evaluate environmental impacts, economic feasibility, catalyst generation, material regeneration, and industrial scale-up.

"The real opportunity is not simply turning waste into carbon. It is turning waste into materials that are useful, affordable and genuinely better for our energy and water future."

Thank you

Questions and Answer

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Welcome collaborations!