4th International Symposium
on
Analytical and Applied Pyrolysis

PYROASIA 2024

International Symposium on Analytical and Applied Pyrolysis

November 28 - 29, 2024

Venue: Indian Institute of Technology Guwahati

ABSTRACT BOOK

From the Chair, PYROASIA 2024

Dear Colleagues and Esteemed Guests,

On behalf of the organizing committee, it is my great pleasure to welcome you all to ***4th International Symposium on Analytical and Applied Pyrolysis (PyroAsia 2024)***, hosted at the Indian Institute of Technology Guwahati. This landmark event, taking place on November 28-29, 2024, serves as a premier forum for experts, researchers, industry leaders, and young professionals in the field of pyrolysis and sustainable energy technologies. The significance of PyroAsia 2024 cannot be overstated. As we face global challenges related to energy security, environmental sustainability, and resource management, the need for innovative and effective thermal conversion technologies has never been more urgent. This symposium aims to harness collective expertise to push the boundaries of research and practical application in this pivotal area.

This year, PyroAsia 2024 has witnessed an overwhelming response, with over 150 high-quality abstracts submitted from researchers and practitioners spanning more than 10 countries. The diversity and depth of these contributions underscore the growing global interest in pyrolysis technologies and their transformative potential. We are proud to present an engaging program featuring keynote presentations, technical sessions, panel discussions, and poster exhibitions, all designed to foster knowledge sharing and collaboration.

IIT Guwahati, known for its strong emphasis on cutting-edge research and interdisciplinary approaches, is the ideal venue for such an event. I believe that the sessions over these two days will not only highlight recent advancements but also inspire new research directions and strengthen the bridge between academia and industry.

I would like to extend my heartfelt thanks to our dedicated organizing team, sponsors, and partners whose tireless efforts have made PyroAsia 2024 possible. To our distinguished speakers, participants, and attendees, I encourage you to actively engage in discussions, explore innovative ideas, and take full advantage of this unique gathering. Once again, welcome to PyroAsia 2024. Let us seize this opportunity to collaborate, innovate, and drive progress in the field of sustainable pyrolysis and energy solutions.

Prof. Kaustubha Mohanty

Chair, PyroAsia 2024

Pyro Asia Forum

The PYROASIA FORUM has been started with an aim to foster a network of researchers, academicians, and industrialists from Asia Region, dedicated to advancing and commercializing pyrolysis and related technologies for future fuel applications and sustainability. We kicked off our annual meeting in 2019 which was hosted by Prof R Vinu at IIT Madras. The subsequent one was organized in 2021 due to Covid-19. The third one was held in Kuala Lumpur Malaysia, hosted by Prof Suchithra, University of Nottingham, Malaysia Campus. This forum has been steadily growing. More and more researchers are joining the forum and use the platform to showcase their research and use the platform for collaboration & networking.

I am glad to see that the fourth annual meeting is being organized by Prof Mohanty at IIT Guwahati. It is great to see that he and his team have put lot of efforts to make 2024 a big and managed to attract many researchers from India to be part of Pyro Asia 2024. Our forum is taking baby steps and growing steadily. One of our forum objective to complement Pyro International Forum by bridging and give more opportunities for upcoming young researchers to get due recognition for their research findings and novelty. Pyro Asia forum has initiated Masters and PhD thesis award from this year to recognize best Thesis in the field of pyrolysis. It is great and much need initiative to promote Pyrolysis research in the region. Once again, I congratulate Prof Mohanty and his team for creating a big stage for Pyrolysis Researchers to showcase their lates research findings and expanding their professional networking.

Dr Sathrugnan Karthikeyan

Pyro Asia Forum

Program Schedule

28-Nov-2024	DAY 1	
8.00-8.55 AM	**Breakfast and Registration**	
9.00-9.25 AM	**Welcome and Inaugural**	
9.30-11.00 AM	**Session-1: Analytical & Applied Pyrolysis of Polymers & Microplastics**	
	Session Chairs: Abhishek Sharma and Kalpit Shah	
9.30-9.50 AM	**Keynote 1**	**Shogo Kumagai, Tohoku University, Japan** Combined UV-irradiation and pyrolysis-GC/MS approach for evaluating the deterioration behavior of PV module encapsulant materials
9.50-9.55 AM	**Questions & Answers**	
9.55-10.10 AM	**Invited 1**	**Atsushi Watanabe, Frontier Laboratories** Application of F-Splitless Pyrolysis-GC/MS to the Analysis of Polymeric Materials
10.10-10.15 AM	**Questions & Answers**	
10.15-10.30 AM	**Invited 2**	**Rajkumar Kasilingam, Indian Rubber Materials Research Institute, Maharashtra** Commercial utilization of end of life tyres to produce high value Chemicals and fuel using integrated technology
10.30-10.35 AM	**Questions & Answers**	
10.35-10.50 AM	**Invited 3**	**Young-Min Kim, Daegu University, South Korea** New filtration system for microplastic analysis using Py-GC/MS and its application in environmental and food sample analysis
10.50-10.55 AM	**Questions & Answers**	
11.00-11.30 AM	**Tea & Coffee**	
11.30-1.00 PM	**Session-2A (Parallel Session): Microwave Pyrolysis & Product Characterization**	
	Session Chairs: Suchithra Thangalazhy Gopakumar and Ejaz Ahmad	
11.30-11.45 AM	**Invited 4**	**Arshad Adam Salema, Monash University, Malaysia** Microwave processing of biomass: Temperature measurement, energy consumption and syngas characteristics
11.45-11.50 AM	**Questions & Answers**	
11.50-12.05 PM	**Invited 5**	**B. Rajasekhar Reddy, IIT-ISM Dhanbad** Microwave-assisted Pyrolysis of Mixed Plastic Waste: Role of Interactions on liquid Yields and Quality
12.05-12.10 PM	**Questions & Answers**	
12.10-12.25 PM	**Invited 6**	**Manoj Tripathi, Jaypee Institute of Information Technology, Noida** RSM Optimization of process parameters in microwave pyrolysis of mustard (*Brassica nigra*) husk (MSH) for the development of biomass-derived supercapacitor electrode
12.25-12.30 PM	**Questions & Answers**	
12.30-12.40 PM	**Short Oral 1**	**Priyanka Katiyar, Shiv Nadar Institute of Eminence, Noida** Reimagining Aroma Extraction Waste: Catalytic Pyrolysis for Hydrocarbon Production
12.40-12.42 PM	**Questions & Answers**	
12.42-12.52 PM	**Short Oral 2**	**Miranti Budi Kusumawati, Tohoku University, Japan** Co-pyrolysis of vacuum residue and bio-oil: A detailed liquid product characterization

12.52-12.54 PM	**Questions & Answers**	
12.54-1.04 PM	**Short Oral 3**	**Mukul Agrawal, Shiv Nadar Institute of Eminence, Noida** Comparative distribution and characterization of products from fast pyrolysis of cooked food waste, eucalyptus (wood), and bamboo (non-wood)
1.04-1.06 PM	**Questions & Answers**	
11.30-1.00 PM	**Session-2B (Parallel session): Analytical Pyrolysis**	
	Session Chairs: Prasenjit Mondal and Sankar Chakma	
11.30-11.45 AM	**Invited 7**	**R. Vinu, IIT Madras** Analytical Pyrolysis of common polymers using different pyrolysis systems: Effect of heating rate and timescale on product distribution
11.45-11.50 AM	**Questions & Answers**	
11.50-12.05 PM	**Invited 8**	**Pratik N. Sheth, BITS-PILANI, Rajasthan** Chemical analysis of Refuse Derived Fuel (RDF)
12.05-12.10 PM	**Questions & Answers**	
12.10-12.20 PM	**Short Oral 4**	**Takaya Satoh, JEOL Ltd., Japan** Development of a quantitative method for a trace amount of microplastics by pyrolysis GC/MS/MS
12.20-12.22 PM	**Questions & Answers**	
12.22-12.32 PM	**Short Oral 5**	**Takao Fukudome, JEOL Ltd., Japan** Rapid analysis of pyrolysis oil using blank tube-FI method and GC-EI/FI method
12.32-12.34 PM	**Questions & Answers**	
12.34-12.44 PM	**Short Oral 6**	**Janejira Ratthiwal, Thammasat University, Thailand** HDPE bottle cap waste upgrading through two-stage catalytic pyrolysis using Tandem Microreactor-GCMS
12.44-12.46 PM	**Questions & Answers**	
12.46-12.56 PM	**Short Oral 7**	**Swati Sharma, IIT Mandi** In-situ Transmission Electron Microscopy for understanding pyrolysis of polymers for device fabrication
12.56-12.58 PM	**Questions & Answers**	
1.00-2.00 PM	**LUNCH**	
2.00-4.00 PM	**Session-3: Biochar and Advances in Analytical Instrumentation**	
	Session Chairs: Arshad Salema and S. Murugavelh	
2.00-2.20 PM	**Keynote 2**	**Suchithra Thangalazhy Gopakumar, University of Nottingham, Malaysia** Effect of torrefaction of biomass for co-digestion of palm oil mill effluent
2.20-2.25 PM	**Questions & Answers**	
2.25-2.40 PM	**Invited 9**	**Hendrix Yulis Setyawan, Universitas Brawijaya, Malang, Indonesia** Experimental study of pyrolysis product utilisation: Phosphate-Doped Biochar as fertiliser
2.40-2.45 PM	**Questions & Answers**	
2.45-3.00 PM	**Invited 10**	**Senthilmurugan Subbiah, IIT Guwahati** Pyrolysis Reactor for Sustainable Biochar Production
3.00-3.05 PM	**Questions & Answers**	

3.05-3.25 PM	**Sponsors Slot 1**	**Thermo Fisher Scientific India Pvt. Ltd.** **Sunil Kumar**
3.25-3.45 PM	**Sponsors Slot 2**	**JEOL, India**
4.00-4.45 PM	**Tea & Coffee**	
4.45-7.00 PM	**Session-4A (Parallel Session): Modelling in Biomass Pyrolysis (Kinetics, AI/ML models)**	
	Session Chairs: Shogo Kumagai and Sanjeev Yadav	
4.45-5.00 PM	**Invited 11**	**Himanshu Goyal, IIT Madras** First-principles and ML modeling of biomass thermochemical conversion
5.00-5.05 PM	**Questions & Answers**	
5.05-5.20 PM	**Invited 12**	**Anjireddy Bhavanam, NIT Jalandhar** Co-pyrolysis of torrefied rice straw and coal: thermal behavior and kinetic analysis
5.20-5.25 PM	**Questions & Answers**	
5.25-5.40 PM	**Invited 13**	**Chinta Sankar Rao, NIT Surathkal** Leveraging Explainable AI for Predictive Modeling of Product Yields from Lignocellulosic Biomass Using Machine Learning
5.40-5.45 PM	**Questions & Answers**	
5.45-5.55 PM	**Short Oral 8**	**Deepak Bhushan, IIT Roorkee** Multi-parameter optimization and predictive modeling of pyrolysis of walnut shells using response surface methodology and machine learning algorithms
5.45-5.47 PM	**Questions & Answers**	
5.47-5.57 PM	**Short Oral 9**	**Kartik S, UPL University of Sustainable Technology, Vadodara** Catalytic Cracking of Plastic waste fractions: Kinetic and Thermodynamic parameter estimation through non-linear approach
5.57-6.00 PM	**Questions & Answers**	
6.00-6.10 PM	**Short Oral 10**	**Zi Wei Ng, Monash University, Malaysia** Exergy, CO_2 Emission, and Techno-Economic Analysis of DME Production via EFB Biomass Gasification
6.10-6.12 PM	**Questions & Answers**	
6.12-6.22 PM	**Short Oral 11**	**Hemant Balsora, UPL University of Sustainable Technology, Vadodara** Artificial Neural Network Based Models for the Prediction of Pyrolysis Product Distribution Using Preliminary Analysis
6.22-6.24 PM	**Questions & Answers**	
6.24-6.34 PM	**Short Oral 12**	**Pritam Kumar, IIT Madras** Pyrolysis of Blends of Rice Husk with Bagasse and Wood Chips: Pyrolysate Composition Analysis and Distributed Activation Energy Modeling
6.34-6.36 PM	**Questions & Answers**	
4.45-7.00 PM	**Session-4B (parallel session): Catalytic Pyrolysis and HDO**	
	Session Chairs: Pankaj Tiwari and Pratik Seth	
4.45-5.00 PM	**Invited 14**	**N. Sivamohan Reddy, IIT Roorkee** Catalytic Effect on the Degradation Behavior of Metal loaded Biomass
5.00-5.05 PM	**Questions & Answers**	
5.05-5.20 PM	**Invited 15**	**Anjana P A, NIT Warangal**

		Heterogeneous catalysts in Pyrolysis reaction
5.20-5.25 pm	**Questions & Answers**	
5.25-5.40 PM	**Invited 16**	**Samuel L. Rokhum, NIT Silchar** Development of superhydrophobic biochar catalyst for biodiesel production
5.40-5.45 PM	**Questions & Answers**	
5.45-5.55 PM	**Short Oral 14**	**Saimatun Nisa, IIT Jammu** Catalytic and non-catalytic pyrolysis of walnut shell waste
5.55-5.57 PM	**Questions & Answers**	
5.57-6.07 PM	**Short Oral 15**	**Santoshnambi Yadav, IIT Kharagpur** Bio-oil production from lipid-rich microalgal biomass grown in open raceway system: An analytical Py-GCMS study
6.07-6.09 PM	**Questions & Answers**	
6.09-6.19 PM	**Short Oral 16**	**Prabu Marimuthu, IIT Madras** Synergistic Catalytic Insights: Noble Metals supported on Ni-based Perovskite Catalysts for Enhanced Hydrodeoxygenation of Guaiacol
6.19-6.21 PM	**Questions & Answers**	
6.21-6.31 PM	**Short Oral 17**	**Pikesh Kumar, IIT Guwahati** Conversion of lignocellulosic biomass to 5-HMF over bifunctional metal-loaded biochar catalyst with biphasic solvent
6.31-6.33 PM	**Questions & Answers**	
6.33-6.43 PM	**Short Oral 18**	**Janaki Komandur, IIT Guwahati** Catalytic Hydrodeoxygenation of bio-oil produced from biomass and plastic waste
6.43-6.45 PM	**Questions & Answers**	
6.45-6.55 PM	**Short Oral 19**	**Munmi Bhattacharyya, IIT Guwahati** One-pot green synthesis of NiO/MgO nano-composite catalyst for the thermo-catalytic devolatilization studies of sawdust pyrolysis and its comparative analysis with industrial zeolite and dolomite bulk catalysts
6.55-6.57 PM	**Questions & Answers**	
7.00-8.00 PM	**Posters and Networking**	
8 PM onwards	**Dinner**	
29-NOV-2024	**DAY 2**	
8.00-8.55 AM	**Breakfast and Registration**	
9.00-10.30 AM	**Session-5: Industry Perspectives of Biomass Pyrolysis and Emerging Contaminants**	
	Session Chairs: R. Vinu and Sathrugnan Karthikeyan	
9.00-9.15 AM	**Invited 17**	**Chiranjeevi Thota, Bharat Petroleum Corporation Ltd.** Co-Processing of Renewable and Recyclable Feedstocks in Fluid Catalytic Cracking Units
9.15-9.20 AM	**Questions & Answers**	
9.20-9.35 AM	**Invited 18**	**Kalpit Shah, RMIT Melbourne** Exploring the fate of PFAS in biosolids pyrolysis through pilot-plant trials
9.35-9.40 AM	**Questions & Answers**	
9.40-9.55 AM	**Invited 19**	**Sanjeev Yadav, Shiv Nadar Institute of Eminence, Noida** Two-phase formation in a bio-oil from pyrolysis of mixed food waste from the kitchen

9.55-10.00 AM	**Questions & Answers**	
10.00-10.20 AM	**Academic Partner 1**	**Sanjeev Yadav, Shiv Nadar Institute of Eminence, Noida**
10.20-10.35 AM	**Academic Partner 2**	**Abhishek Sharma, Manipal University, Jaipur**
10.35-11.00 AM	**Tea and Coffee**	
11.00-1.00 PM	**Session-6A (Parallel Session): Biochar and Applications-I**	
	Session Chairs: V.V. Goud and Deepak Ojha	
11:00-11.15 AM	**Invited 20**	**S.V. Srinivasan, CSIR CLRI, Chennai** Pyrolysis of bulk Organic Fractions of Municipal Solid Waste (OFMSW) generated from cities
11.15-11.20 AM	**Questions & Answers**	
11:20-11.35 AM	**Invited 21**	**Nanda Kishore, IIT Guwahati** Preparation, Chemical Activation and Catalytic Application of Pyrolytic Biochar Derived from *Delonix regia*
11.35-11.40 AM	**Questions & Answers**	
11.40-11.55 PM	**Invited 22**	**Bunushree Behera, Thapar Institute of Engineering and Technology** Influence of Feedstocks and Activation Methods for Sustainable Applications of Biochar: Perspectives on Energy-Water-Food Nexus
11.55-12.00 PM	**Questions & Answers**	
12.00-12.10 PM	**Short Oral 20**	**Bhavya Tripathi, BITS-PILANI, PILANI CAMPUS** Biochar from dried neem leaves & cotton waste: production, characterization & implementation
12.10-12.12 PM	**Questions & Answers**	
12.12-12.22 PM	**Short Oral 21**	**Nimesha Rathnayake, RMIT Melbourne** Optimizing Biomethane Potential and Biochar Production via Co-Digestion and Pyrolysis/Gasification of Food and Garden Organics with Activated Sludge
12.22-12.24 PM	**Questions & Answers**	
12.24-12.34 PM	**Short Oral 22**	**Mariappan Mani, IIT Madras** Comprehensive characterization and passivation strategies of biochar for safe storage stability
12.34-12.36 PM	**Questions & Answers**	
12.36-12.46 PM	**Short Oral 23**	**Puja Priyadarshini Nayak, IIT Guwahati** Optimization of pyrolysis parameters for biochar production from Kodo Millet (*Paspalum scrobiculatum*) husk and characterization of the product as a precursor for activated carbon synthesis
12.46-12.48 PM	**Questions & Answers**	
12.48-12.58 PM	**Short Oral 24**	**Saurav Kandpal, MNNIT Allahabad** Multi-Target Prediction of Biochar Yield and HHV using ensemble of decision trees
12.58-1.00 PM	**Questions & Answers**	
11.00-1.00 PM	**Session-6B (Parallel Session): Product Diversification from Pyrolysis of Biomass and Plastics**	
	Session Chairs: Hendrix Y Setyawan and K.P. Shadangi	
11.00-11.15 AM	**Invited 23**	**Murugavelh S, VIT Vellore**

		A Circular Economy Approach to Convert Waste Cooking Oil into Value Added Products Towards a Sustainable Environment
11.15-11.20 AM	**Questions & Answers**	
11.20-11.35 AM	**Invited 24**	**Rohidas Bhoi, MNIT Jaipur** Biomass Derived Pyro-oil as Bitumen Modifier in Pavement Construction
11.35-11.40 AM	**Questions & Answers**	
11.40-11.55 AM	**Invited 25**	**Rupam Kataki, Tezpur University** Non-fuel applications of biowastes pyrolysis products: A Sustainable Approach to Resource Recovery for Circular Economy
11.55-12.00 PM	**Questions & Answers**	
12.00-12.10 PM	**Short Oral 25**	**Sivasankar Kakku, Manipal Univeristy, Jaipur** Thermal Up-Cycling of XLPE Waste from Wire Industries via 7.5 TPD Pyrolysis Plant
12.10-12.12 PM	**Questions & Answers**	
12.12-12.22 PM	**Short Oral 26**	**Shaikh Khizar, IIT Madras** Recovery Potential of Plastics and Plastic Blends Through Catalytic and Non-Catalytic Pyrolysis: A Comparative Study Using Analytical Pyrolysis Techniques
12.22-12.24 PM	**Questions & Answers**	
12.24-12.34 PM	**Short Oral 27**	**Indra Mohan, IIT-ISM Dhanbad** Production of renewable liquid oil from pistachio shells and low-density polyethylene through co-pyrolysis
12.34-12.36 PM	**Questions & Answers**	
12.36-12.46 PM	**Short Oral 28**	**Subhan Kumar Pal, IIT Madras** Recovery of Petrochemicals from Oxygenated Aromatic Plastic Wastes using Red Mud via Thermo-catalytic De-polymerization
12.46-12.48 PM	**Questions & Answers**	
12.48-12.58 PM	**Invited 26**	**Sakthivadivel D, VIT Vellore** Performance Enhancement of a Dual Bed Vapor Adsorption Refrigeration System using Cupro-Nickel Coated Biochar as Adsorbent
12.58-1.00 PM	**Questions & Answers**	
1.00-2.00 PM	**LUNCH**	
2.00-4.00 PM	**Session-7A (Parallel Session): Pyrolysis in Gasification, Combustion, HTL and Hydrogenation**	
	Session Chairs: Young-Min Kim and Nanda Kishore	
2:00-2.15 PM	**Invited 27**	**Jaganathan VM, NIT Trichy** Oxy-rich combustion studies of menstrual pads using counter-current biomass packed bed reactor
2.15-2.20 PM	**Questions & Answers**	
2.20-2.35 PM	**Invited 28**	**Mahendra Chinthala, NIT Rourkela** Sustainable production of commodity chemicals using biomass via Chemical Looping Combustion (CLC)
2.35-2.40 PM	**Questions & Answers**	
2.40-2.55 PM	**Invited 29**	**Ashish N. Sawarkar, MNNIT Allahabad** Recent Trends and Future Perspectives on Co-gasification of Petroleum Coke and Biomass

2.55-3.00 PM	**Questions & Answers**	
3.00-3.10 PM	**Short Oral 29**	**Afaq Ahmad Khan, IIT-ISM Dhanbad** γ-Al_2O_3 Supported Bimetallic Catalyst with Controlled Metal Stoichiometric Ratios for Turquoise Hydrogen and Carbon Nanotubes Production
3.10-3.12 PM	**Questions & Answers**	
3.12-3.22 PM	**Short Oral 30**	**Anusha C. Halageri, IIT Madras** Solid Carbon and Hydrogen production by Methane pyrolysis using non-thermal plasma
3.22-3.24 PM	**Questions & Answers**	
3.24-3.34 PM	**Short Oral 31**	**Pooja Singh, IIT Guwahati** A comparative study of bio-oil production via two-stage and direct hydrothermal liquefaction process from microalgae grown on dairy wastewater
3.34-3.36 PM	**Questions & Answers**	
3.36-3.46 PM	**Short Oral 32**	**Shanku Pratim Borah, IIT Guwahati** Hydrothermal liquefaction of Luffa cylindrica to produce levulinic acid
3.46-3.48 PM	**Questions & Answers**	
2.00-4.00 PM	**Session-7B (Parallel Session): Pyrolysis of Biomass, Plastic Oils & Mixtures-I**	
	Session Chairs: B. Rajashekar Reddy and N. Sivamohan Reddy	
2.00-2.15 PM	**Invited 30**	**Sankar Chakma, IISER Bhopal** Mechanistic Investigation in Co-Pyrolysis of Biomass and Waste Plastic for Liquid Fuel Production
2.15-2.20 PM	**Questions & Answers**	
2.20-2.35 PM	**Invited 31**	**Krushna Prasad Shadangi, VSSUT Orissa** Waste to Energy through Co-pyrolysis of Waste Lubricating oil and Waste Plastics
2.35-2.40 PM	**Questions & Answers**	
2.40-2.55 PM	**Invited 32**	**Tarak Mondal, IIT Ropar** Turning Waste into Wealth: Pyrolysis of Biomass and Plastics for Fuels and Chemicals
2.55-3.00 PM	**Questions & Answers**	
3.00-3.15 PM	**Invited 33**	**Ejaz Ahmad, IIT-ISM Dhanbad** A comprehensive strategy for the transformation of waste to wealth for circular economy and sustainable development
3.15-3.20 PM	**Questions & Answers**	
3.20-3.30 PM	**Short Oral 33**	**Abhisek Sahoo, IIT Delhi** Insights into Biomass Pyrolysis: Particle Devolatilization and Structural Behavior via X-Ray Imaging and High-Pressure TGA
3.30-3.32 PM	**Questions & Answers**	
3.32-3.42 PM	**Short Oral 34**	**Bibari Boro, IIT Guwahati** Effect of copper on kinetic parameters and pyrolysis product characterization of waste printed circuit board
3.42-3.44 PM	**Questions & Answers**	
3.44-3.54 PM	**Short Oral 35**	**Nair Theertha Kunhikrishnan, Manipal University, Jaipur** Bio-oil Component Separation Via Integrated Experimental and Modelling Analysis

3.54-3.56 PM	**Questions & Answers**	
4.00-4.45 PM	**Tea and Coffee, Posters and Networking**	
4.45-6.00 PM	**Session-8A (Parallel Session): Pyrolysis of Biomass, Plastic Oils & Mixtures-II**	
	Session Chairs: C.S. Rao and Anjana P.A.	
4.45-5.00 PM	**Invited 34**	**Deepak Kumar Ojha, IIT Roorkee** Pyrolysis driven valorization of textile waste into value-added products
5.00-5.05 PM	**Questions & Answers**	
5.05-5.20 PM	**Invited 35**	**Ranjeet Kumar Mishra, Manipal Institute of Technology, Manipal** Pyrolysis behaviours and kinetic study of non-edible waste castor seeds into renewable liquid fuel and value-added chemicals
5.20-5.25 PM	**Questions & Answers**	
5.25-5.40 PM	**Invited 36**	**Prasenjit Mondal, IIT Roorkee** Sustainable utilization of waste plastics in advancing circular economy: Some studies
5.40-5.45 PM	**Questions & Answers**	
5.45-5.55 PM	**Short Oral 36**	**Bablu Alawa, ICMR-National Institute for Research in Environmental Health, Bhopal** Removal of Emerging Pollutants (*Ciprofloxacin antibiotics*) from Wastewater Using Waste Biomass: A Kinetics, Isotherms, and Thermodynamics Study
5.55-5.57 PM	**Questions & Answers**	
4.45-6.00 PM	**Session-8B (Parallel Session): Biochar and Applications-II**	
	Session Chairs: Tarak Mondal and Bunushree Behera	
4.45-5.00 PM	**Invited 37**	**Soumya Pandit, Sharada University** Unlocking Clean Energy with Novel Biochar-(Fe_2O_3) Ferric Oxide Nanocomposite as Anode Catalyst in Microbial Fuel Cell
5.00-5.05 PM	**Questions & Answers**	
5.05-5.15 PM	**Short Oral 37**	**Yashasvi Trivedi, Manipal University, Jaipur** Pyrolysis-Engineered RDF char: Enhancing Fixed Bed Column Performance
5.15-5.17 PM	**Questions & Answers**	
5.17-5.27 PM	**Short Oral 38**	**Shushree Prachi Palai, KIIT Bhubaneswar** Pyrolysis of Algal Biomass for Sustainable Biochar Production: Investigating the Interplay of Processing Parameters and Material Properties
5.27-5.29 PM	**Questions & Answers**	
5.29-5.39 PM	**Short Oral 39**	**Onkar Chowkekar, IIT Guwahati** Potential of Pyrolysis as an effective technique for Red category Bio-medical waste management.
5.39-5.41 PM	**Questions & Answers**	
5.41-5.51 PM	**Short Oral 40**	**Harjeet Nath, Tripura University** Pyrolyzed Rubber Wood Biochar as a Soil Amendment Agent: Impact on Water Retention and Okra Yield in Smart Irrigation Systems
5.51-5.53 PM	**Questions & Answers**	
6.00-6.30 PM	**Closure and Valedictory Session**	

Poster	Poster Title
Poster 1	**Deepraj Sarkar, MNIT MAHE, Karnataka** Fabrication of biofilms using plant-based extract for the food packaging application: A review
Poster 2	**Tanushka Florence Panicker, MNIT MAHE, Karnataka** Pyrolysis behaviours and kinetic study of non-edible waste castor seeds into renewable liquid fuel and value-added chemicals
Poster 3	**Sowkhya Naidu, Manipal University Jaipur** Temperature-Dependent Pyrolysis of Biomass Feedstocks: Chemical Characterization of Bio-Volatiles from Cashew Nuts and Pine Needles
Poster 4	**Anurag Jaswal, IIT Ropar** Optimizing Pine Needle Pyrolysis: Role of Chemical and Thermal Pretreatment
Poster 5	**Bhawana Bharti, MNNIT Allahabad, Prayagraj** Kinetic and thermodynamic analysis of pyrolysis of microalgal biomass: using model free approaches
Poster 6	**Shahista Farhee, IIT Kanpur** Characterization and nutrient availability of biochar produced from slow pyrolysis of commercially cultivated spirulina
Poster 7	**Rakhi Giri, Manipal University Jaipur** Impact of Agricultural Waste-Derived Biochar on Rice Seed (*Oryza sativa*) Germination and Growth: A Study of Varying Concentrations
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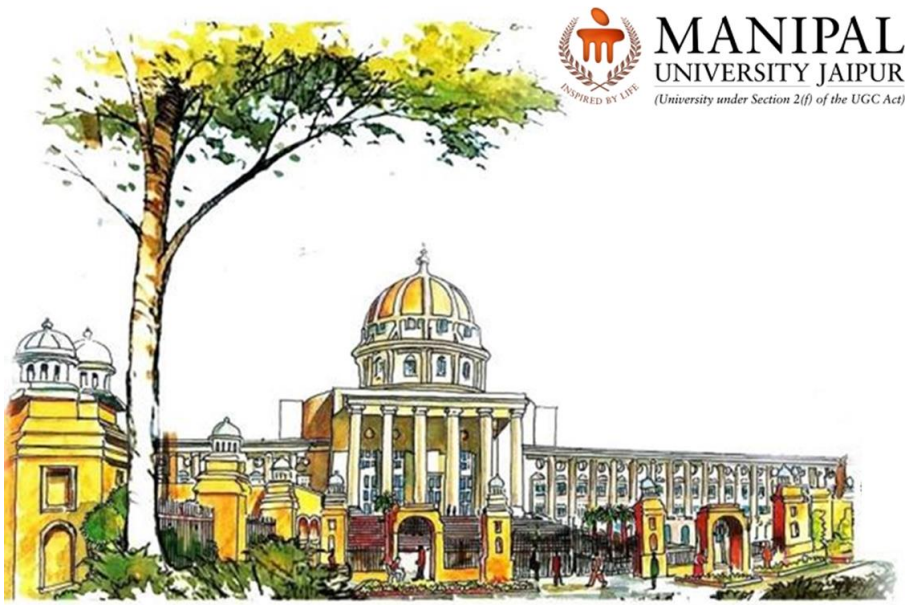

Invited Lectures

PYROASIA 2024
International Symposium on Analytical and Applied Pyrolysis

Mechanistic Investigation in Co-Pyrolysis of Biomass and Waste Plastic for Liquid Fuel Production

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ABSTRACT

The increasing global energy demand, coupled with environmental concerns, calls for the development of advanced, sustainable, and cleaner fuel production methods. This study examines the potential of co-pyrolysis, a promising thermochemical conversion technique, to produce hydrocarbon-rich fuel from a blend of low-density polyethylene and rice husk biomass. The research focuses on analyzing the thermal degradation process and evaluating the properties of the resulting co-pyrolyzed fuel. Experimental tests were conducted to assess key physicochemical properties, including energy content, elemental composition, density, viscosity, and stability. The results indicate that co-pyrolysis of LDPE and rice husk produces a hydrocarbon-rich fuel with favorable combustion characteristics. This fuel exhibits higher energy content and lower viscosity compared to individual feedstocks, making it a viable alternative to conventional petroleum-based fuels. FTIR and NMR analyses identified several functional groups, primarily aromatic compounds, acids, phenols, water, esters, and ethers. Furthermore, NMR analysis confirmed that the addition of waste plastics increases the aromatic content while reducing the paraffinic compounds. A GC-MS analysis also revealed a significant increase in hydrocarbons and a reduction in oxygenated products when LDPE waste plastic was included in the feedstock mixture.

Keywords: Biomass; Co-Pyrolysis; Fuel Composition; Fuel Properties Characterization; Performance

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Microwave-assisted Pyrolysis of Mixed Plastic Waste: Role of Interactions on Liquid Yields and Quality

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ABSTRACT

According to Organisation for Economic Co-operation and Development (OECD 2021) report, the global production of the plastic is keep increasing annually by 4% and about 391 million metric tons (MMT) of plastic is produced in 2021. Therefore, it is essential to implement effective waste plastic management and recycling. Among the different recycling processes, microwave assisted pyrolysis (MAP) is a very efficient process because of its fast, volumetric, uniform, and selective heating. Plastics exhibit very low microwave heating absorbing ability, necessitating the use of a susceptor. In this work, we report MAP of mixture of high-density poly (ethylene) (HDPE) and poly (ethylene terephthalate) (PET) using SiC susceptor. We study the effect of microwave power (280 W, 420 W and 560 W) and HDPE and PET blend ratio (75:25, 50:50 and 25:75) on product yields and quality. This study also focuses on the interaction between HDPE and PET during pyrolysis. A two factor Central Composite Design (CCD) was adopted to design the experiments, and the results were analysed through Response surface methodology. At the 280 W, the liquid yield (wt.%) of HDPE: PET blends 100:0, 75:25, 50:50 and 25:75 is 61.1, 59.6, 63.3 and 30.6 respectively. The liquid yield (wt.%) of 50:50 HDPE: PET blend at MW powers of 280W, 420W and 560W are 63.3 > 48.6 > 46.9 respectively. The GC-MS and FTIR analysis revealed that there are significant interactions in the vapor phase that resulted in a huge variation in the liquid composition.

Keywords: Central Composite Design; Co-pyrolysis; HDPE; Microwave; PET; Plastics

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Waste to Energy through Co-pyrolysis of Waste Lubricating oil and Waste Plastics

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ABSTRACT

Waste lubricating oil (WLO) is generated from used lubricants that have lost their effectiveness due to contamination and degradation. However, waste plastics (WPs) are primarily generated from municipal solid waste and industrial processes. The accumulation of plastic waste in landfills poses significant environmental challenges. Both WLO and WPs offer opportunities for sustainable management and energy recovery, contributing to a circular economy and reducing environmental impact thorough pyrolysis and co-pyrolysis process. The co-pyrolysis of such feedstock requires optimization concerning to the operating temperature, composition of feed stocks, and reactor specifications. This study reflects the effect of blending of WEO and WPs during co-pyrolysis on the yield, quality of wax free pyrolysis oil. The optimization of the process was based on the pyrolysis temperature and blending of WLO and WPs along with higher heating value pyrolysis oil. The results indicated the application in the field of fuel and chemical. The catalytic effect on the yield, quality and composition of pyrolysis oil resulted the effective of the process for commercialization in industrial scale.

Keywords: Aromatic fuels; Catalyst; Fuels; High value pyrolysis oil; Wax free pyrolysis oil

Co-pyrolysis of Torrefied Rice Straw and Coal: Thermal Behavior and Kinetic Analysis

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ABSTRACT

This study emphasizes on unravelling two environmental problems; mitigation of CO_2 emissions and paddy straw burning. As co-firing seems to be a viable option in solving the above problems, in this work an effort is done in understanding the Co-pyrolysis behavior of torrefied rice/paddy straw with coal. The rice straw was collected from the villages near nakodar region in Punjab. In this study, the rice straw used was torrefied at 220 °C. This torrefaction temperature was chosen from the maximum calorific value observed. Torrefaction improved the energy density of the biomass. Five different mixing ratios (1:0, 1:1, 1:4, 4:1 and 0:1) of rice straw and coal were tested using thermogravimetric analysis at three different heating rates (10, 15 and 20 °C/min). The decomposition rate curves showed two distinct reaction zones for torrefied rice straw and coal blends. The kinetic parameters and synergistic effects between lignocellulosic biomass and coal were identified by using model free methods. This study will understand the thermal behavior during the co-firing and also predict the production of possible value added products. The data generated will further expedient for development of saleable processes.

Keywords: Co-pyrolysis; Coal; Kinetics; Rice Straw; Thermogravimetric analysis

Co-authors names: Vishal Kashyap, Subhrajeet Dash, Sumer Singh Meena, Anee Mohanty, GN Nikhil

Influence of Feedstocks and Activation Methods for Sustainable Applications of Biochar: Perspectives on Energy-Water-Food Nexus

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ABSTRACT

Urbanization concomitant with industrial growth have led to significant environmental deterioration over years. To address the pressing concerns, thermochemical conversion strategies for agro-residue management facilitating biochar production intended for varied industry applications has gained significant traction. Carbon based catalysts, adsorbents and biofertilizers are increasingly being employed in environmental applications. The present talk delves into specific research strategies involved in production and modifications of biochar under different conditions for varied applications covering nexus of energy, soil and water. Production temperature and physicochemical modification methods have been shown to govern surface properties of biochar, thereby its functional efficiency. Addition of sulphonic acid groups onto biochar surface was observed after acid treatment facilitating its use as a heterogenous solid catalyst for transesterification. 94.91% biodiesel yield was observed with methanol: oil ratio of 20:1, at 5% w/v biochar dosage, 65 °C after 4 h. Further, chemical modification with inorganic salts has been shown to increase in positive surface functional charges paving its use as a natural flocculant to harvest 90% microalgae in an hour. This nutritional rich algae-biochar composite can be used as a biofertilizer. Similarly, electrochemical modification was seen to enhance the surface properties and hydroxyl functional groups over pristine biochar, resulting in 94% phosphate recovery with adsorbate concentration of 100 mg/L at dosage of 6 g/L biochar at neutral pH. Nonetheless, these studies in a consolidative manner provides probable supportive evidences, paving forward the use of biochar-based refinery in the realm of sustainable bioprocessing.

Keywords: Biochar; Biorefinery; Catalysts; Modifications; Resource recovery

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A Comprehensive Strategy for the Transformation of Waste to Wealth for Circular Economy and Sustainable Development

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ABSTRACT

Unprecedented technological developments and the pursuit to upgrade the peculiarity of living standards have become a benchmark to indicate the overall growth of any nation. However, rapid technological changes and the urge to improve further have also caused a detrimental effect on the environment, disproportionate exploitation of resources, and huge amounts of discarded waste materials. In particular, the exponential increase in greenhouse gas emissions and accumulation of solid waste, including agro residue, waste plastic, and e-waste, are of major concern, which necessitates the development of technologies that can effectively utilize these waste materials as a resource to achieve the objective of sustainable development goals and circular economy. In this regard, high-temperature pyrolysis technologies have shown promising results for using solid waste as a resource to produce fuel, turquoise hydrogen, hydrogen-rich syngas, and energy for a circular economy. Moreover, high-temperature technologies can also be extended to conventional fossil fuels such as coal, coalbed methane, and natural gas to produce turquoise hydrogen and carbon nanotubes. Similarly, low-temperature conversion technologies have been developed to produce chemicals such as biopolymers, fuel additives, green gasoline, green diesel, and sustainable aviation fuel from solid waste-derived intermediate molecules. Therefore, the current study elucidates a comprehensive strategy for transforming waste into wealth via high- and low-temperature technologies for circular economy and sustainable development.

Keywords: Biopolymer; Circular economy; Sustainable aviation fuel; Turquoise hydrogen; Waste management

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First-principles and ML Modeling of Biomass Thermochemical Conversion

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ABSTRACT

Biomass pyrolysis in fluidized bed reactors is a promising technique to convert waste biomass into value-added chemicals and fuels. This process involves coupling of multiple physico-chemical processes at different scales. The product yield and composition of the pyrolysis products depend on the coupling among devolatilization reactions at molecular scale, transport processes coupled with devolatilization reactions at particle scale, and multiphase hydrodynamics at reactor scale. Accurate predictions of reactor dynamics require a multiscale modeling approach, where adequate models are used to represent the processes at different scales. This work integrates a detailed kinetic model for devolatilization chemistry and a one-dimensional intraparticle model with a CFD-DEM model. Both the chemistry model and the intraparticle model have been rigorously validated with the experimental measurements. The developed multiscale framework is assessed against experiments and used to explore the impact of particle-scale processes on the overall reactor performance. Moreover, existing ML algorithms are used to reduce the simulation time of CFD simulations and post-processing of the CFD data. This work is step towards developing first-principle models to optimize and scale-up real-life complex multiphase reactors for emerging clean energy technologies, such as thermochemical conversion of biomass into chemicals and biofuels.

Keywords: Biomass pyrolysis; CFD; Fluidized bed reactors; Machine learning

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Leveraging Explainable AI for Predictive Modeling of Product Yields from Lignocellulosic Biomass Using Machine Learning

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ABSTRACT

This study investigates the predictive modeling of product yields from lignocellulosic biomass pyrolysis using machine learning and Explainable Artificial Intelligence (XAI) techniques. The model incorporates a variety of input features, including the proximate and ultimate analyses of biomass (such as carbon, hydrogen, and volatile matter content), as well as pyrolysis reaction conditions (temperature, heating rate, and time). A comprehensive set of machine learning algorithms: Random Forest, AdaBoost Regressor, CatBoost, Decision Tree, Extra Trees, Gradient Boosting Tree, Extreme Gradient Boosting, Rotation Forest, and Light-GBM along with Support Vector Regression, Gaussian Process Regression, and Artificial Neural Networks, were applied to train the models. Model performance was evaluated using RMSE, MAPE, and R^2 indices, with XGB exhibiting the best performance (MSE: 2.584, R^2: 0.985), followed by RF and GBT. In addition, SHAP (SHapley Additive exPlanations) analysis was employed to elucidate feature importance, providing insights into the key factors influencing bio-oil yield predictions. The results show that temperature is the most critical variable, with the highest mean SHAP value, followed by heating rate, time, and hydrogen content. These variables exhibit a significant impact on model predictions, while features such as moisture content, volatile matter, and ash show relatively lower contributions. The SHAP beeswarm and bar plots visually demonstrate the varying influence of these input variables on the predicted outcomes, thereby enhancing model interpretability and trustworthiness for biomass conversion processes.

Keywords: Biomass; Explainable AI; Machine Learning; Pyrolysis; SHAP

Co-authors names: Maheswata Lenka and Potnuri Ramesh

Experimental Study of Pyrolysis Product Utilisation: Phosphate-Doped Biochar as Fertiliser

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ABSTRACT

This study explores the potential of phosphate-doped biochar as a sustainable slow-release fertilizer, focusing on biochar produced through pyrolysis from various biomass from agricultural residues (corncob, rice husk, bagasse). The biochar was impregnated with various commercial phosphate fertilizers, including Monoammonium Phosphate (MAP), Diammonium Phosphate (DAP), and SP-36 (a low-grade commercial phosphate fertilizer), each at three impregnation ratios (0.5:1, 1:1, and 3:1 P/B). The effectiveness of these phosphate-doped biochar was evaluated based on key characteristics such as ash content, fixed carbon, and phosphate solubility in 2% citric acid and water, and phosphate leaching from the biochar. The results indicate that increasing phosphate-to-biochar ratio significantly influences the properties of biochar and its nutrient retention capacity. Water content rises with higher phosphate ratios, especially in P_2O_5-treated bagasse biochar. Ash content also increases with higher phosphate ratios, with rice husk biochar exhibiting the highest ash levels, and SP-36 contributing the most substantial increase due to its higher mineral content compared to other phosphate sources. Volatile matter content rises as phosphate ratios increase, particularly in DAP and MAP-treated biochar, with MAP showing the most significant increase. In contrast, fixed carbon content decreases as phosphate ratios rise, especially in corncob biochar. Phosphate retention, measured in citric acid and water, improves with higher phosphate ratios, with DAP being the most effective phosphorus source, achieving nearly 100% retention at a 3:1 ratio, followed by MAP and P_2O_5, while SP-36 was the least effective. All phosphorus sources exhibit an initial peak and gradual release in leached phosphate concentration. P_2O_5 leaching from SRF biochar shows the quickest release compared its counterparts.

Keywords: Phosphate-Doped Biochar; Pyrolysis; Phosphorus Availability; Slow-Release Fertilizer; Sustainable Agriculture

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Microwave Processing of Biomass: Temperature Measurement, Energy Consumption and Syngas Characteristics

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ABSTRACT

Although microwave (MW) technology provides several advantages, such as rapid, volumetric, and non-contact heating, it also suffers from problems and shortcomings. For instance, measuring real-time temperature during MW irradiation is challenging, and there is a lack of data on energy consumption for MW biomass processing. Far too little attention has been paid to syngas characteristics obtained from MW gasification (MWG) of oil palm biomass. Thus, the main aim of the research was to present oil palm biomass gasification in a lab-scale MW system to unravel the temperature measurements, energy consumption, and syngas characteristics. Experiments were carried out in a 1.25 kW lab-scale MW system facilitated with a quartz reactor, cavity, and metallic thermocouples placed from the top and the bottom of the MW cavity. Numerical simulation was carried out, and its results were experimentally validated, showing the effect of placing the metallic thermocouple on the temperature and electric field distribution. The most striking result was the interaction of the thermocouple with the MW electric field in the top configuration that created localized heating, inaccurate temperature readings (error ± 120 °C), low MW energy absorbance (peak value 91 W), and MW leakage (> 10 mW/cm2). Interestingly, a very reliable temperature reading (error ± 20 °C) with high MW power absorption (peak value 273 W) was observed when the metallic thermocouple was placed from the bottom of the cavity. The highest total gas yield of 63.3% and a gas heating value of 9 MJ/kg were found at 40% MW power and 10% absorber loading. The specific energy consumption continued to decrease with increasing absorber loading. Overall, the findings from this research work will provide a new dimension to scale up the MW biomass processing technology.

Keywords: Biomass; Gasification; Microwave; Syngas; Temperature

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Pyrolysis Behaviours and Kinetic Study of Non-Edible Waste Castor Seeds into Renewable Liquid Fuel and Value-Added Chemicals

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ABSTRACT

A thorough understanding of the characteristics of biomass pyrolysis offers essential insights into the design of pyrolysis equipment and process optimisation. The present study focused on thermal decomposition profiles, kinetics analysis, bio-oil and biochar production. The kinetic analysis of castor seeds (CS) was performed using the Friedman (FM), Ozawa-Flynn-Wall (OFW), Starink (STM), Kissinger-Akahira-Sunose (KAS), and Criado model. However, the bio-oil and biochar were produced in a semi-batch reactor at 450, 500 and 550 °C, 50 °C.min^{-1} heating rate, and 100 mL.min^{-1} inert gas flow rate. The average apparent activation energy of CS from KAS, OFW, ST, and FM was found to be 172.75, 174.21, 173.03, and 156.47 kJ mol^{-1}, respectively. The thermal decomposition profile of CS was confirmed by increasing heating rates from 10-50 °C.min^{-1}, and TGA curves shifted towards a higher temperature zone. Further, the pyrolysis test confirmed 48±0.95 bio-oil, 15±0.74 biochar and 37±0.68 syngas, respectively, at 500 °C. The characterisation of bio-oil confirmed improved properties of bio-oil (reduced oxygen content, increased carbon content and higher heating value) at 500 °C than at 450 and 550 °C. Further, the characterisation of biochar confirmed 55% carbon, 1.6% hydrogen, 16.12 MJ.kg^{-1} heating value, and 585 kg.m^{-3} bulk density. Also, FTIR and SEM analysis of biochar (CSB) confirmed that CSB is rich in aromatic compounds and has a very rough surface structure.

Keywords: Biochar; Bio-oil; Catalysts; Kinetics parameters; Non-edible seeds; Pyrolysis

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Performance Enhancement of a Dual Bed Vapor Adsorption Refrigeration System using Cupro-Nickel Coated Biochar as Adsorbant

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ABSTRACT

This study explores the characterization of cupro-nickel-coated biochar and its utilisation over the novel adsorbent material for dual bed vapor adsorption refrigeration system (DB-VARS). The surface characteristics of cupro-nickel coated biochar using advanced electroless coating were meticulously studied and presented. This coating process results with the decreased surface area and pore volume along with the increased thermal conductivity of the biochar, significantly enhances its adsorption capacity. These augmentations place cupro-nickel-coated biochar as a promising material for improving the efficiency of DB-VARS. The DB-VARS is designed to utilize biomass as an energy source to generate hot water at temperatures ranging from 90°C to 120°C. The performance of DB-VARS was scrupulously ascertained under six different operational conditions, yielding Coefficient of Performance (COP) values of 0.67, 0.71, 0.74, and 0.70 for standalone Cold Storage Room (CSR) and Bulk Milk Chiller (BMC) configurations, both with and without loading. In hybrid operations, the system has accomplished with a COP values of 0.65 with loading and 0.60 for without loading. The system has reached a maximum Specific Cooling Power (SCP) of 12 kW under peak operational conditions. The analysis shows that the proposed system is economically viable and environmentally benign, providing sustainable cooling technology with a payback period of 3.6 years. The enhanced characteristics of the cupro-nickel-coated biochar contribute to the overall efficiency of the DB-VARS, providing a green and sustainable solution for rural agro-storage and cooperative societies.

Keywords: Adsorption; Biomass; Biochar; Electroless coating; Refrigeration

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RSM Optimization of Process Parameters in Microwave Pyrolysis of Mustard (*Brassica nigra*) Husk (MSH) for the Development of Biomass-Derived Supercapacitor Electrode

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ABSTRACT

Biomass has offered a huge potential in energy production and storage applications. Biomass-derived electrodes, due to their lower cost and high charge storage capacity are becoming popular for energy storage applications. Microwave pyrolysis is a promising technique to produce highly carbonaceous porous char suitable for supercapacitor electrodes. Efficiency and effectiveness of microwave pyrolysis significantly depends on its process parameters. This study focuses on optimization of the process parameters during the microwave pyrolysis of mustard (*Brassica nigra*) husk (MSH) to maximize the mustard husk char (MSHC) yield and its BET surface area using Response Surface Methodology (RSM). Three process parameters considered in this study *viz.* microwave power (MWP), radiation time (RDT) and nitrogen flow rate (NFR) significantly affect the yield and BET surface area of synthesized MSHC. This study also developed a regression model to predict yield and BET surface area of synthesized MSHC. ANNOVA analysis of the regression model offers F-test value and p-value to be 149.39 and 0.0001 respectively, ensuring higher reliability of model. The linear regression coefficient (R^2) is 0.98 for MSHC yield and 0.99 for MSHC BET surface area. Study predicted that the combination of MWP (111.3 W), RDT (42.7 min) and NFR (131.4 m^2/min) will produce MSHC with yield (51.7%) and BET surface area (303.2 m^2/g). The predicted results were validated by synthesizing the MSHC under optimized conditions and the experimental results were deviated only by 5.41% and 5.50% for yield and BET surface area respectively, indicating that the developed model is quite reliable and may be used to predict the yield and BET surface area of synthesized char.

Keywords: Biomass electrode; Microwave pyrolysis; Process parameters; RSM optimization; Supercapacitor electrode

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Exploring the Fate of PFAS in Biosolids Pyrolysis through Pilot-Plant Trials

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ABSTRACT

Conventional methods for managing biosolids have not proven effective in eliminating per- and polyfluoroalkyl substances (PFAS) present in them. Currently, only thermal treatments—such as pyrolysis, incineration, and gasification—show promise for large-scale PFAS destruction. Among these methods, pyrolysis is preferred because it not only produces biochar but also generates bioenergy and reduces toxic gas emissions. However, the behavior of PFAS during the pyrolysis of biosolids is not well understood, as it is often assumed that PFAS will simply volatilize during the process.

This work involved pilot-plant trials aimed at investigating the fate of PFAS during pyrolysis. The trials utilised a novel fluidised bed pyrolysis process developed by RMIT University. Comprehensive analyses of PFAS and total fluorine content were conducted on all solids, liquids, and gases collected at multiple sampling points. Composite samples of biosolids and biochar were tested for 28 targeted PFAS compounds, while scrubber water samples were analyzed for 36 components. Gas samples were collected from the exits of the pyrolysis reactor, the thermal oxidizer (TO), and the scrubber, and were assessed for total PFAS and hydrogen fluoride.

The results indicated that the total PFAS concentration in the biosolids was 58.1 ng/g, with PFAS levels in the biochar and scrubber water dropping below detection limits. Additionally, gas-phase PFAS concentrations at the TO and scrubber exits were undetectable, indicating a significant level of PFAS destruction. Only 6.4 ng/m³ of PFAS was detected at the exit of the pyrolysis reactor, suggesting that pyrolysis is somewhat effective in reducing PFAS. However, the methods used for gas sampling and analysis require further refinement. The fluorine mass balance analysis revealed that the majority of fluorine in the biosolids originates from non-PFAS sources. The biochar retained 95% of the fluorine, while the scrubber successfully captured gaseous fluorine.

Keywords: Biosolids; PFAS; Pyrolysis

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A Circular Economy Approach to Convert Waste Cooking Oil into Value Added Products Towards a Sustainable Environment

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His Significant projects include serving as the Principal Investigator for a project on the "Co-pyrolysis of agro-biomass with plastic waste for bio oil production in a tubular reactor," funded by the Science and Engineering Research Board (SERB), Government of India. I am also the Co-investigator for a project on developing direct injection technology for hydrogen-enriched CNG and biogas, funded by the Department of Science and Technology, Government of India.
In addition to my research, I have been involved in two industrial projects, hold two granted patents, and have authored over 60 articles published in peer-reviewed journals.

ABSTRACT

The pyrolysis of waste cooking oil (WCO) and plastics, such as LDPE, has attracted attention from both researchers and industry due to the potential to produce valuable fuels from waste materials. To maximize fuel yield while minimizing energy input, key process parameters like feedstock blend ratios and temperature must be optimized. This study explores the optimization of these parameters and the techno-economic viability of producing diesel-equivalent fuel from WCO and LDPE. A full-factorial experimental design was conducted, varying six temperatures and seven blend ratios to assess oil yields. The highest bio-oil yield of 65% was achieved at 500°C with a 2:1 WCO to LDPE blend. Additionally, pyrolyzed WCO and a 1:1 blend of WCO and LDPE were evaluated for fuel properties, meeting ASTM standards for Grade No. 2 and Grade No. 4 diesel, respectively. Techno-economic analysis revealed a payback period of under 14 months for both fuel types. An attempt has been made to convert the waste cooking oil into bio-asphalt for road construction. A 1:1 blend of WCO and LDPE bio-asphalt shares similar chemical characteristics with conventional asphalt binder. This approach allows for the reuse of waste cooking oil and plastic (LDPE) as a sustainable asphalt component.

Keywords: Bio-asphalt; Co-pyrolysis; Low Density Polyethylene (LDPE); Techno-economic analysis; Waste cooking oil (WCO)

Oxy-rich Combustion Studies of Menstrual Pads Using Counter-Current Biomass Packed Bed Reactor

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ABSTRACT

Oxy-fuel combustion studies of menstrual pads using biomass as a renewable energy source is presented here. Experiments are carried out in a canonical counter current reactor with ligno-cellulosic biomass burning in combustion regime. Additional oxygen is provided inside the reactor and thereby providing a conducive ambient of sanitary pad burning is explored unlike conventional electric incinerators. Agro-based residue pellets, Prosopis Juli flora and Cashew nutshell were used as representative fuels burning with a fuel flux of about 70 g/m^{2}s at a superficial velocity of 15 cm/s. The average peak bed temperature reaches about 1000 – 1200 °C, where sanitary pads with moisture fraction of 0.54, 0.77, 0.85 and 0.9 (by wt.) were incinerated inside the biomass reactor in diffusion mode. Three oxygen flow rates; 1, 3 and 6 lpm were injected at the bottom of the pad grate and burning time was measured and process was monitored. The temperature at the exit of the reactor was measured to ensure sufficient temperature throughout the burning period of pads. High temperature (about 1200 – 1400 °C) maintained inside the reactor near the pad burning grate which eliminates the formation of dioxins and ensure safe incineration. The maximum pad burn rate was found to be around 0.5 g/s at an oxygen flow rate of 6 lpm. The char left out after burning is collected and characterized for unburnt carbon and ash content. The optimum parameters derived from the packed bed experiment will be used to build a practical scale, low cost, continuous, self-sustainable menstrual pad incinerators.

Keywords: Biomass; Combustion; Enriched air; Incinerators; Menstrual pads

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Chemical Analysis of Refuse Derived Fuel (RDF)

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ABSTRACT

The conversion of municipal solid waste (MSW) into refuse-derived fuel (RDF) and its application as an alternative fuel is gaining traction. However, RDF's highly heterogeneous nature, with a complex composition that varies by season and source, poses challenges. This study focuses on the chemical characterization of six RDF samples, labeled A through F, collected from different locations nationwide. Various analytical methods were employed, including pyrolysis gas chromatography-mass spectrometry (Py-GC/MS), thermogravimetric analysis (TGA), and CHONS elemental analysis. Qualitative and semi-quantitative data were gathered using evolved gas analysis (EGA), single-shot, and double-shot techniques. The EGA results were correlated with TGA for qualitative analysis. Functional characterization was further investigated through FTIR analysis, while XRF and ICP-MS triple quad analyses provided insights into the inorganic composition of the samples. The single-shot analysis indicated that long-chain alkenes were most abundant, following non-hydrocarbon gases like CO_2 and O_2, along with alkanes, aromatic compounds, and ketones. Double-shot analysis revealed the presence of chloride and sulfur compounds, which are limiting factors in RDF. The contribution of polystyrene to the lower heating value (LHV) of RDF was also highlighted. The findings can be used for future studies on RDF composition and its pyrolytic behavior in gasifiers, thereby enhancing future gasifier models, where pyrolysis plays a critical role. This technique proves useful for a more comprehensive characterization of both volatile and non-volatile fractions of pyrolytic products.

Keywords: Chemical characterization; Municipal solid waste; Pyrolysis; Refuse-derived fuel; Thermal analysis techniques

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Two-phase Formation in a Bio-Oil from Pyrolysis of Mixed Food Waste from the Kitchen

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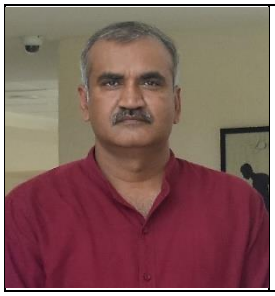

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ABSTRACT

In recent years, pyrolysis, a thermochemical conversion method, has been shown as a potential food waste management technique. In this study, different process conditions for the pyrolysis of food waste were tested for enhanced bio-oil production. First, the slow pyrolysis was conducted with a low heating rate 10 °C/min and low to medium temperature (300–500 °C), producing the highest yield (~41%) at 500 °C, with single phase and very high aromatic content (~60%). Thereafter, various heating rates were tested by keeping the temperature constant (500 °C) and it was found the increase in heating rate resulted in the separation of bio-oil into the aqueous and oil phase. The heating rate of 50 °C/min produced the bio-oil with the highest overall yield and with the largest fraction of the oil phase. In a further study, the temperature and heating rate were kept constant at optimal conditions obtained previously i.e. 500 °C temperature and 50 °C/min heating rate, but the hot vapor residence time (HVRT) was varied from 40 sec to 2 sec. The results showed that a decrease in HVRT decreased the light fraction or aqueous fraction of bio-oil and increased the dark fraction or oil fraction. Moreover, the chemical composition of the dark phase exhibited promising results as it contained a high amount of esters (80–90%) which increased on decreasing the HVRT. A large fraction of them are fatty acid methyl esters (FAMEs) which could directly be used as biodiesel without any further treatment.

Keywords: Bio-oil; Food waste; Pyrolysis; Syngas; Two phases

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Non-fuel Applications of Biowastes Pyrolysis Products: A Sustainable Approach to Resource Recovery for Circular Economy

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ABSTRACT

Biowastes, including agricultural residues, agro-industrial wastes, municipal solid waste (MSW), sludge, and various other biowastes, are ubiquitously available. Their effective utilization can address multiple environmental and economic challenges. By converting these biowastes through pyrolysis, we can significantly reduce open burning practices, a major contributor to air pollution, mitigate greenhouse gas emissions, conserves natural resources. Additionally, this conversion process majorly generates biooil, a renewable energy source, and biochar, which can be used for end number of applications, fostering a circular economy/bioeconomy and promoting sustainable development. Bio-oil, a versatile liquid product derived from the pyrolysis of biomass, is not merely a fuel but a treasure trove of chemicals. Its diverse chemical composition, rich in oxygenated compounds like alcohols, aldehydes, ketones, and phenols, makes it a promising feedstock for various non-fuel applications. These include the production of fine chemicals, such as pharmaceuticals, cosmetics, and agrochemicals. Bio-oil can also be used as a bitumen replacement or additive in road construction. Biochar, a carbon-rich solid product, is widely used as a valuable soil amendment. Its porous structure and high surface area make it an excellent adsorbent for various pollutants, including heavy metals, organic contaminants, and nutrients. Biochar can be incorporated into asphalt mixtures to create bioasphalt, a more sustainable alternative to traditional asphalt. Biochar's porous structure and high carbon content improve the mechanical properties of asphalt, enhancing its durability, fatigue resistance, and resistance to thermal cracking. The current review explores the diverse applications of biowaste pyrolysis products, to address various environmental challenges and contribute to a sustainable future.

Keywords: Biochar; Biooil; Biowastes; Circular Economy; Pyrolysis

Recent Trends and Future Perspectives on Co-gasification of Petroleum Coke and Biomass

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ABSTRACT

In the light of recent advances all over the world regarding usage of fossil fuels, petroleum refineries are investing significantly in newer approaches to meet an ever-increasing demand of environmentally benign products. Amongst various conversion processes in refineries, delayed coking process is still the most sought-after option for refiners in view of the flexibility of the process in handling a variety of feedstocks including those containing significant amount of asphaltenes. This process generates a significant amount of a solid by-product, while maximizing liquid hydrocarbons yield, known as petroleum coke which is also called as petcoke. Petcoke is a carbonaceous material like coal. However, petcoke has high heating value and low ash content as compared to coal. At the same time, it has high sulphur content vis-a-vis coal, which is one of the major challenges for petcoke to be employed as a fuel. Lately, a lot of interest is generated in undertaking investigations to derive energy from inferior quality petcoke containing appreciable amount of sulphur and metals (nickel and vanadium, in particular) through co-gasification with biomass. Co-gasification is being explored not only for the production of energy but also for chemicals. Co-gasification is being touted as a potentially sustainable approach which nullifies the challenges associated with the gasification of petcoke alone as well as biomass alone, to a significant extent. In the present communication, basics of co-gasification of petcoke and biomass will be discussed. Furthermore, challenges and future perspectives pertaining to co-gasification of petcoke and biomass will also be deliberated.

Keywords: Biomass; Co-gasification; Petroleum coke; Sustainability; Synthesis gas

Heterogeneous Catalysts in Pyrolysis Reaction

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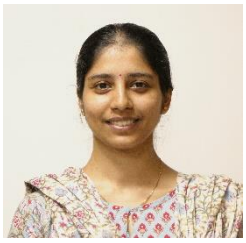

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ABSTRACT

The demand for alternative and sustainable fuel sources is concurrently rising across the globe with industrialization, environmental concerns and growth in the global population. Reliable and efficient fuel produced from biomass and plastic waste as feedstock has attracted in recent years. Solid, liquid and gaseous products with fuel-like property can be obtained from the pyrolysis of biomass or plastics. However, the quality and quantity of specific product is highly dependent on the process parameters, rector type and feedstock quality, additionally upon the nature of the catalyst adopted for the pyrolysis process that assures higher heating value and stable liquid biofuel with narrow product distribution. Moreover, catalyst presence reduces reaction time and declines pyrolysis reaction temperature significantly from 700 °C to around 400 °C. Molecular sieves, such as zeolites, have been widely used as catalysts for pyrolysis applications in the recent years. Three-dimensional aluminosilicates consisting of corner sharing [TO_4] (T = Si, Al) tetrahedral crystals are called zeolites. Highly porous structure with tuneable acidity and interconnected cavities or channels that can control the product distributions has several applications in catalysis. The strong acid site, low hydrogen transfer activity, hydrothermal stability and specific pore structure with high product selectivity of ZSM-5 catalyst promotes the pyrolysis reaction with better product selectivity and distribution.

Keywords: Bio-oil; Catalysts; Char; Fe_2O_3; Pyrolysis; Zeolite

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Sustainable Utilization of Waste Plastics in Advancing Circular Economy: Some Studies

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ABSTRACT

The concept of circular economy has been gaining popularity in recent years as a means of achieving sustainable development. One of the key components of this model is the transformation of waste into valuable resources. Plastic wastes in municipal solid wastes and its management is an important issue in current years. Among different types of waste plastics packaging plastics comprising LDPE, HDPE as well as PP create maximum environmental impacts. Recycling of this type of plastic wastes is a major concern since very few technologies are available for their recycling. Among different types of recycling processes secondary and tertiary processing (pyrolysis) are more suitable for handling this type of waste plastics. Life cycle analysis can also help evaluate the environmental impact of these processes and products, and identify areas for improvement to increase their sustainability. Hence, the technical aspects of waste plastics recycling trough pyrolysis and secondary processing, product upgradation, and life cycle analysis and their potential for producing high-value products from waste plastics, as well as the economic and environmental benefits of these approaches are discussed. Some of the challenges that need to be addressed to promote the wider adoption of pyrolysis as a key technology for advancing the circular economy are also highlighted.

Keywords: Circular economy; LCA; Pyrolysis; Recycling; Waste plastics

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Sustainable Production of Commodity Chemicals Using Biomass via Chemical Looping Combustion (CLC)

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ABSTRACT

Traditional chemical production often contributes to significant pollution, greenhouse gas emissions, and resource depletion. In contrast, sustainable practices seek to reduce these impacts by promoting cleaner production methods. One promising approach is transitioning to renewable feedstocks, such as biomass or waste materials, which can ensure a more dependable supply of raw materials.

This simulation study explores a sustainable method for ammonia (NH_3) production by integrating biomass-derived syngas with Chemical Looping Combustion (CLC). In this process, biomass serves as the primary feedstock, producing synthesis gas (syngas) through gasification. The study examines the use of this syngas within a CLC system, utilizing a Fe2O3/Fe3O4 carrier to efficiently convert nitrogen into ammonia.

The integration of CLC not only enhances the conversion efficiency but also offers inherent carbon capture capabilities, leading to cleaner combustion and a reduced carbon footprint. Additionally, the study provides valuable insights into optimizing key parameters for improved syngas and hydrogen production, establishing a solid foundation for sustainable and efficient ammonia synthesis.

Keywords: Ammonia; Biomass; Chemical looping combustion; Gasification; Hydrogen

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Pyrolysis of Bulk Organic Fractions of Municipal Solid Waste (OFMSW) Generated from Cities

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ABSTRACT

Urban cities generate significant quantity of municipal solid waste (MSW) and disposal of these wastes in open dumpsites result in environmental pollution. It also results in emission of greenhouse gases causing global warming. In urban area, considerable portion of bulk quantity of wastes are generated from vegetable, fruit, flower, slaughterhouse, and fish markets and these wastes are organic in nature which could be utilized for generation of energy through Anaerobic Digestion (AD). Apart from the above-mentioned wastes, some other bulk wastes generated such as banana peduncle, tender coconut, sugarcane bagasse etc., which also generated in urban cities are rich in fibrous, which cannot be treated using conventional AD and composting processes, and needs some special treatment. Pyrolysis is one such treatment that could be suitable for this fibrous waste (FW). Pyrolysis process converts FW into biochar and energy, but the constrain is presence of high moisture content upto 85 to 90% in these FW. Hence, in this study, a novel approach of solar drying with lessor/no energy was also carried out prior to pyrolysis to reduce the moisture content to make these FW more amenable for pyrolysis. Lab scale pyrolysis studies were carried initially with different temperatures and heating rates with FW. Based on the lab scale studies, a pilot study has been carried through combined solar drying and pyrolysis (single chamber pyrolysis). In this pyrolysis process, dried fibrous waste is pyrolyzed with its own calorific value of the substrate (fibrous waste) without any external heating source at the bottom chamber and the pyrogas formed from FW is combusted in the top chamber of pyrolyser with air supplied through the blower. During pyrolysis operation, the temperature in the range of 430 °C to 500 °C was achieved and about 32.6% of biochar was obtained. Similarly, heat energy equivalent to 86.829 kJ/sec of energy is generated in the form of hot water from the heat exchanging system in the pyrolyser. The characteristics of biochar such as pH, CEC, organic carbon, EC, available phosphorus, potassium and micro nutrients has been determined and it showed that the biochar is more suitable for soil reclamation as well as soil conditioner with carbon sequestration potential meeting the objectives of Indian national missions of Smart City, Swachh Bharat and UN sustainable development goals.

Keywords: Anaerobic digestion; Biochar; Fibrous waste; Pyrolysis; Thermal Energy

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Pyrolysis Driven Valorization of Textile Waste into Value-Added Products

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ABSTRACT

Textile waste generation has increased remarkably worldwide due to the substantial clothing trends among mankind. Consequently, textile waste is leading to an exhaustive impact on resources and the environment. The heterogeneous compositional nature and slow decomposition rate lead to the non-viable reclamation of textile waste, which is a challenge for technologies intending to recycle such waste. To prevail over these challenges, it is important to search for a sustainable approach to the recovery of energy from textile waste rather than the disposal of waste to the environment. This study employs the pyrolysis process to explore the valorization of textile waste into value-added products. Therefore, the present work deals with the slow pyrolysis of two different types of textile waste, i.e., denim and cotton waste, to obtain bio-oil in a semi-batch reactor conducted at 500 °C. The denim jeans were pyrolyzed originally as well as post dye removal. The dye from the denim waste was removed by treating the denim waste with nitric acid. The ultimate analysis, thermogravimetric analysis, and HHV (High Heating value) of textile waste were carried out. The product distribution of cotton waste, treated and untreated denim, along with their characteristics, were analyzed using Gas Chromatography-Mass Spectrometry. Further, the biochar was characterized using Fourier-transform infrared spectroscopy (FTIR) and X-ray diffractometer (XRD). The surface morphological feature and elemental composition of raw denim and cotton waste and its corresponding biochar after pyrolysis were also characterized by Field emission scanning electron microscopy (FESEM). The compositional data of bio-oil of different textile wastes used in this study revealed the presence of furans compounds, ketones, alcohol, phenolic compounds, esters, nitrogenous compounds, and others in the bio-oil sample. Thus, textile waste can serve as potential for energy recovery.

Keywords: Product characterization; Textile waste valorization

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Catalytic Effect on the Degradation Behavior of Metal loaded Biomass

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ABSTRACT

This study investigated the pyrolytic behavior, kinetic, and thermodynamic parameters of raw and metal-impregnated sugarcane bagasse (using Ni, Ru, and Fe), Fe/Cu impregnated water hyacinth through thermogravimetric analysis at heating rates of 5, 10, 15, and 20 °C/min. The metals were incorporated into the lignocellulosic matrix as nano-oxides/hydroxides, significantly lowering activation energy (SB-Ni: 62.50 kJ/mol; SB-Ru: 78.46 kJ/mol; SB-Fe: 83.09 kJ/mol) and enhancing weight loss (SB-Ni: 88.03 wt%; SB-Ru: 85.46 wt%; SB-Fe: 82.33 wt%).

Additionally, the study addressed the potential of using water hyacinth, a harmful plant that extracts heavy metals from water, as a feedstock for bio-oil and carbon hybrids via pyrolysis. Characterization of Fe/Cu-impregnated samples showed average particle sizes of 15.3 nm and 116 nm, respectively. Pyrolysis yielded maximum conversions of 68% for Fe and 48% for Cu-impregnated biomass, with kinetic modeling confirming results. The metal-impregnated water hyacinth resulted in lower activation energy for reaction in comparison with the raw water hyacinth. The ΔH_α (168.9 kJ.mol^{-1}) and ΔG_α (164.9 kJ.mol^{-1}) are maximum for the raw water hyacinth in comparison with metal-impregnated samples, signifying the higher energy requirement for breaking reactant bonds.

Overall, metal impregnation reduces the activation energy required for pyrolysis, indicating a promising method to improve biomass conversion efficiency and produce valuable biofuels and chemicals. This approach may help mitigate the harsh conditions typically associated with biomass pyrolysis.

Keywords: Activation energy; Metal impregnation; Pyrolysis; Sugarcane Bagasse; Water hyacinth

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Development of Superhydrophobic Biochar Catalyst for Biodiesel Production

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ABSTRACT

The engineering of wettability in functional materials is an area of great interest, particularly for developing superhydrophobic catalysts. These catalysts are essential for preventing the poisoning of active sites by water, whether generated in situ or as a by-product. In this study, we introduce for the first time a superhydrophobic spherical activated carbon catalyst (SSAC@PhSO3H), synthesized through a novel approach and applied in the production of biodiesel from Jatropha curcas oil (JCO).

This catalyst boasts an impressive surface area of 1461 m^2g^{-1}, a high acid density of 6.26 mmol g^{-1}, and a water contact angle of 163.4°, showcasing exceptional performance and significant water repellency that underscores its superhydrophobic nature. Utilizing Response Surface Methodology based on Central Composite Design (RSM-CCD), we predict a maximum biodiesel yield of 98.8% under optimal conditions (80 °C, 5 wt% catalyst, a 15:1 methanol-to-oil molar ratio, and a reaction time of 40 minutes).

Life Cycle Cost Analysis (LCCA) estimates the production cost of biodiesel at 0.37 USD per kg, highlighting its strong commercial potential. Compared to H_2SO_4-sulfonated biochar, SSAC@PhSO3H retains a yield of 86.8 ± 0.4% even after nine reaction cycles, demonstrating remarkable stability and preserving its spherical morphology. Furthermore, the fuel properties of JCO biodiesel conform to European Norm EN 14 212 and ASTM D6757 standards, reinforcing its viability.

Keywords: Biochar; Biodiesel; Energy; Life Cycle Cost Analysis; Sustainability

Commercial Utilization of End of Life Tyres to Produce High Value Chemicals and Fuel Using Integrated Technology

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Presently working as Director, IRMRI, Under DPIIT, Ministry of Commerce & Industry, Govt of India. He is Chairman – BIS- PCD 29, Member – BIS – PCD 13, ISO TC 45, BIS-TED 7, BIS – ME17, BIS – PCD 28 etc. Dr. Rajkumar has total 22 years of experience in rubber Compound development, cost reduction, Rubber Product Development, Failure investigation, Test Methods development, Polymer nanocomposites. He is Involved in indigenization of projects for Defence and Nuclear sectors. He received several awards like appreciation from Nuclear Recycle Board, BARC for indigenization of Rubber Gauntlet, NAIP award – 2012 for successful execution of Rubber Dam project sponsored by World bank, from ICAR, Ministry of Agriculture, Govt. of India from the hands of Governor of Goa and Minister of MP, Bharat Seva Ratan Gold Medal in the year 2016 from GEPRA, ISO TC 45 – Long service award (2019) for contribution to international standardization, Fellow of Indian Textile Association. He had nobility of attending JRMA seminar at Japan, Tokyo as Indian Technical Expert on behalf of BIS & received appreciation from President, Japan Standardization Committee in the year 2006, 2007 & 2014.

ABSTRACT

This study focused on waste management strategies for tire components to mitigate environmental harm from dumping and incineration. Pyrolysis was conducted in a rotary kiln in inert atmosphere, yielding three primary products: char, oil, and syngas. The syngas served as an energy source for the pyrolyzer, while the oil was distilled to extract valuable chemicals, including limonene. Raw pyro-char was validated in conveyor belt formulations against commercially available carbon black. In preliminary stage, raw pyro-char exhibited inferior properties compared to commercial carbon blacks (N-330, N-550), surface modifications were anticipated to enhance its performance. EDX analysis confirmed the presence of sulfur and zinc oxide (ZnO) in the pyro-char. In compounding trials, a 50% reduction in ZnO was successfully achieved, resulting in a 25% increase in tensile strength. These findings indicate that modified pyro-char can serve as a viable alternative in industrial applications, contributing to sustainable waste management practices. The distillation of raw pyro-oil revealed the existence of limonene with a retention time of 9.471 minutes in GCMS study, accounting for 14.61% of the total peak area, highlighting its significant presence and potential for industrial applications in pherma after further treatment. Overall, this research demonstrates the promise of pyrolysis-derived products in addressing waste management challenges while fostering environmentally friendly practices in the tire industry.

Keywords: End of life tyres; Limonene; Regenerated carbón; Thermo-chemical pyrolysis; Waste tyre

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Unlocking Clean Energy with Novel Biochar-(Fe_2O_3) Ferric Oxide Nanocomposite as Anode Catalyst in Microbial Fuel Cell

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ABSTRACT

This research demonstrated how employing a combination of biochar and ferric oxide (Fe_2O_3) nanocomposite as a catalyst for the anode may enhance the power output of a microbial fuel cell (MFC). Fe_2O_3 nanoparticles and biochar, distinguished by their increased surface area and conductivity, were combined to create a composite material. Improving microbial activity and electron transport was the aim of this combination. The nanocomposite was examined using a variety of techniques, such as Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and X-ray diffraction (XRD). The synthesized nanocomposites were used as a catalyst on the anode electrode. The charge-discharge study, polarization study, cyclic voltammetry, electrochemical impedance spectroscopy, Coulombic efficiency, and other techniques were used to accomplish the electrochemical investigation. The testing results showed significant improvements in power density of up to 13.32 W/m^3, highlighting the composite's potential to boost MFC efficiency. The improved biofilm formation was observed using increasing concentrations of biochar/Fe_2O_3 nanocomposites. The energy recovered as bioelectricity was around 16.34%. Hence, this work demonstrates how biochar and Fe_2O_3 nanocomposites can be used to enhance performance in sustainable energy technologies.

Keywords: Anode Catalyst; Biochar; Microbial Fuel Cell; Nanocomposites

Preparation, Chemical Activation and Catalytic Application of Pyrolytic Biochar Derived from *Delonix regia*

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ABSTRACT

Pyrolytic bio-oil derived from waste biomass has considerable applications but not biochar due to lack of nutrient contents, presence of undesirable functional groups, slow nutrient release and various other reasons. In this study, authors utilized biochar from pyrolysis by activating it using chemical activation methods. Pyrolysis of *Delonix regia* (DR) were carried out at low temperature (400 °C) for 1h to produce sufficiently large quantity of biochar (49.8wt.%). Activating agents selected were a base (KOH), an acid (H_3PO_4) and a salt ($ZnCl_2$). Activated biochars were characterized for their surface morphology, particle size, elemental compositions, functional groups and surface area. H_3PO_4 activation resulted in highest surface area biochar (50 times increase compared to non-activated biochar). Applications of these activated biochars as catalyst were tested in solvolysis of the same biomass, conducted at 250 °C and pressure of 93bar (for both catalytic and non-catalytic cases) using methanol as solvent. Results from these experiments were compared with those obtained by solvolysis using commercial Ni/γ-Al_2O_3 catalyst. Biochar obtained from solvolysis also has high carbon content and thereby high HHV. Results of all catalytic solvolysis experiments were better than non-catalytic ones in terms of yield and HHV of biocrude. Solvolysis with H_3PO_4 activated biochar produced best results in terms of yield of biocrude (28.39wt.%) and HHV (23.89 MJ/kg). Thus, it is concluded that activated biochars had potential to be used as a catalyst in solvolysis.

Keywords: Biochar; Catalyst; Chemical Activation; *Delonix regia*; Solvolysis

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Biomass Derived Pyro-oil as Bitumen Modifier in Pavement Construction

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ABSTRACT

Bitumen, a complex, viscoelastic material derived from crude oil distillation, is an adhesive substance used in pavement construction, ensuring durability and waterproofing. As a non-renewable resource, it is rapidly depleting, necessitating the search for sustainable alternatives for pavement construction. Bio-bitumen, a blend of upgraded pyro-oil and conventional bitumen, emerges as a sustainable binding material from ubiquitous bio-renewable resources. The blend can serve different purposes based on the pyro-oil percentage such as bitumen modifier (<10%), extender (25 – 75%) and alternate binder (100%). The blends were prepared by mixing the residue obtained after pyro-oil distillation and the VG30-grade bitumen. The mixing time and conditioning time are the critical parameters in bio-bitumen preparation. The prepared bio-bitumen was characterised by penetration value (IS: 1203-1978), softening point (IS: 1205-1978), ductility (IS: 1208-1978), flash and fire point (IS: 1209-1978) and viscosity. The penetration value increased by 33.3% when 5% bio-oil was added. Further, the softening point decreased by 1 degree, making the mixture suitable as a binder to be added to petroleum pitch.

Keywords: Binder; Bio-bitumen; Petroleum pitch; Pyro-oil

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Co-Processing of Renewable and Recyclable Feedstocks in Fluid Catalytic Cracking Units

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ABSTRACT

The fluid catalytic cracking (FCC) unit remains a cornerstone of refinery operations, enabling the conversion of heavy residuals into valuable transportation fuels and petrochemical feedstocks. With its inherent flexibility, the FCC can adapt to varying market demands, such as maximizing distillate or petrochemical production. However, the FCC is a significant source of CO_2 emissions, prompting the need for decarbonization strategies. One promising approach is the co-processing of renewable and recyclable feedstock, reducing reliance on fossil fuels and mitigating the carbon footprint of coke combustion. Despite the infancy of FCC co-processing, refiners are exploring alternative feedstocks such as plant-based oils, plastics, and biomass pyrolysis-derived oils. These feedstocks, however, introduce new challenges, including high oxygenates, newer metal contaminants (P, Si, K), and vastly differing chemical compositions. This research investigates the impact of feedstock diversity, highlighting the critical role of FCC units in processing a range of renewable feedstocks while adapting to future sustainability regulations.

Keywords: Bio oil; Co-processing; Fluid Catalytic Cracking; Plastic oil; Renewable feedstocks

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Application of F-Splitless Pyrolysis-GC/MS to the Analysis of Polymeric Materials

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Introduction: When analyzing trace samples in the microgram range using pyrolysis (Py)-GC/MS, use of a lower split ratio or a splitless injection method can increase the detection sensitivity. However, if the carrier gas flow rate in the pyrolyzer is too slow, secondary reactions of pyrolyzates may occur, leading to significant alterations in the peak intensity ratios and patterns of the pyrograms. To suppress the secondary reaction and improve the detection sensitivity, we developed a new sampling device that enables splitless Py-GC/MS measurement with a relatively high carrier gas flow rate for analyzing trace amounts of polymer samples [1]. In this study, we utilized the device to carry out splitless thermal desorption (TD)-GC/MS including double-shot Py-GC/MS and also demonstrated the successful suppression of the secondary reactions for polymer mixtures.

Experimental: The measurement system is shown in Fig. 1. It consists of an auto-shot sampler (AS-2020E, Frontier Laboratories Ltd. (F-Lab)) and a micro-furnace pyrolyzer (EGA/PY-3030D, F-Lab) connected directly to the GC injector of a GC/MS system. The newly developed sampler (MFS-2015E, F-Lab) is set in the GC system using a splitter located between the pre-column (UA precolumn 50-1M, F-Lab) and the separation column (UA^{+}5-30M-0.5F, F-Lab).

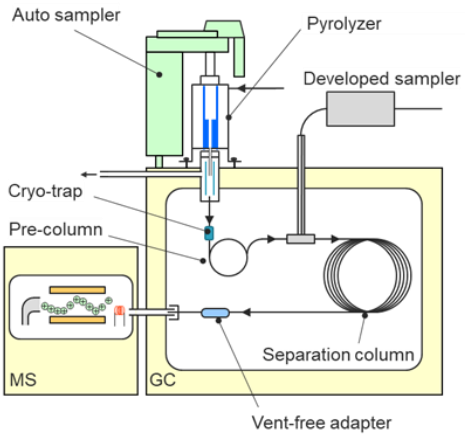

Fig. 1 Splitless Py-GC/MS system

Results and Discussion: First, a 0.1 mg polystyrene sample containing 1 ng of phenanthrene was analyzed using splitless TD-GC/MS, followed by split Py-GC/MS. The phenanthrene recovery rate via TD-GC/MS was 99.8%, and no carryover was detected in the pyrogram obtained from the subsequent Py-GC/MS measurement. Second, the splitless Py-GC/MS system demonstrated its ability to suppress the secondary reactions in co-pyrolysis of polyvinyl chloride and polyethylene terephthalate. These results show the wide applicability of the splitless Py-GC/MS for characterizing various polymer materials.

Pyrolysis Reactor for Sustainable Biochar Production

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ABSTRACT

This study presents an optimized pyrolysis reactor system developed to convert biomass and municipal solid waste (MSW) into valuable biochar, syngas, and liquid char, effectively repurposing waste as a resource. Trials at NTPC Ramagundam demonstrated the reactor's performance using MSW briquettes from local dump yards. Key operating conditions, including a controlled temperature of up to 500°C and a consistent residence time, yielded high-quality biochar with a Gross Calorific Value (GCV) of 6500 kcal/kg. Comprehensive testing verified the efficient processing of 3 tonnes of MSW daily, supporting NTPC's sustainability goals through waste minimization and energy recovery.

Keywords: Biochar; Biomass; Municipal Solid Waste; Pyrolysis Reactor; Sustainable Waste Management

Turning Waste into Wealth: Pyrolysis of Biomass and Plastics for Fuels and Chemicals

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Dr. Tarak Mondal is a faculty member of department of Chemical Engineering, Indian Institute of Technology Ropar. He did his PhD in Chemical Engineering from the Indian Institute of Technology Delhi and M. Tech in Chemical Engineering from the Indian Institute of Technology Roorkee. Dr. Mondal is an expert of heterogeneous catalysis, reaction engineering, chemical kinetics and modelling. His research area focused on biomass conversion processes, hydrogen production from renewable sources, monitoring exhaust emission, and waste to energy conversion etc. Dr. Mondal is a recipient of Distinction in doctoral research for the year 2016 from IIT Delhi. Dr. Mondal has several publications in international peer reviewed high impact journals. His work has been appreciated by subject peer groups.

ABSTRACT

Biomass, as a renewable and abundant resource, presents a promising solution to the growing need for sustainable energy and fuel alternatives to fossil fuels. Among the various biomass conversion technologies, pyrolysis stands out as a promising thermochemical route to convert biomass into valuable products i.e. bio-oil. However, despite its advantages, bio-oil has several drawbacks that limit its direct application as a fuel. As a result, bio-oil requires further treatment/upgradation to be converted into a high-quality fuel that can be integrated into existing energy infrastructures. Integrated pyrolysis and steam reforming becomes a promising route to convert bio-oil into hydrogen, a clean and versatile energy carrier with broad applications in fuel cells and hydrogen-powered vehicles. In addition, pre-treating the biomass through techniques such as torrefaction, acid/alkali leaching, etc. can enhance the quality of the resulting bio-oil by reducing its oxygen content and improving its stability and energy density. On the other hand, plastic has been one of the most important innovation for the betterment of the living standard of mankind. However, the rate of disposing of waste plastic has risen remarkably and thereby imposing a negative impact on public health and environment. Our investigation describes the effect of thermal and heterogeneous catalytic pyrolysis system on the yield, composition and the nature of the pyrolytic oil produced from various real-world plastic wastes. In this talk, I will explore both Biomass and Plastic waste pyrolysis approaches in detail, discussing their mechanisms, benefits, challenges, and potential impacts on advancing their use as a sustainable energy source. By examining these strategies, the aim is to highlight the role of pyrolysis in the transition to cleaner, renewable fuels and its potential to contribute to the global shift away from fossil-based energy systems.

Keywords: Biomass; Fuels and chemicals; Plastic waste; Pyrolysis; Reforming

Co-authors names: Anurag Jaswal, Piyush Pratap Singh, Subhashini
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Effect of Torrefaction of Biomass for Co-digestion of Palm Oil Mill Effluent

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Suchithra Thangalazhy Gopakumar is an Associate Professor at University of Nottingham Malaysia. Dr. Suchithra's research focuses on the development of liquid biofuels and the extraction of chemicals from various biomass feedstocks through thermo-chemical conversions and catalytic upgrading. She has authored more than 70 journal papers. She is also the recipient of some research grants at the university and national levels. Suchithra has the status of Fellow of the Higher Education Academy, UK, Charted Engineer and Charted Scientist from Institute of Materials, Minerals & Mining, UK. She has membership with IChemE (UK), I.M3 (UK), IIChE (India) IEM (Malaysia) and BEM(Malaysia).

ABSTRACT

Malaysia has been known as one of the world's largest producers of palm oil, playing a pivotal role in the global vegetable oil industry. Palm oil mills generate vast amounts of solid waste during the palm oil extraction process such as empty fruit brunches, palm kernel shells, decanter cake, and palm fronds. Another byproduct generated from palm oil industries is a major concern, which is palm oil mill effluent, also known as POME. POME is a noteworthy waste product where approximately 50 – 75 million m^3 are generated during sterilization, clarification, and oil extraction stages in palm oil mills. Anaerobic digestion (AD) is a type of biological treatment that has been favored as a promising and comprehensive solution for POME treatment. The unpredictability of POME composition is a significant issue because it might affect the content and rate of biogas production. Co-digestion is a technology that involves the simultaneous digestion of multiple organic materials and offers distinct advantage over conventional anaerobic digestion methods. This study evaluated the benefits of torrefaction as a pre-treatment for palm frond (PF) biomass before its co-digestion with POME in an anaerobic environment. PF are considered of bulky nature due to their thick and leathery texture, as well as being large and fibrous nature. Torrefaction, mild pyrolysis, offers a promising avenue for enhancing the characteristics of PF biomass, rendering it more amenable to subsequent anaerobic digestion.

Keywords: Anaerobic co-digestion; Methane yield; Palm Frond; Palm Oil Mill Effluent; Torrefaction

Co-authors names: Daniela Manriquez Milicevic, Yi Jing Chan

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New Filtration System for Microplastic Analysis Using Py-GC/MS and its Application in Environmental and Food Sample Analysis

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Prof. Young-Min Kim specializes in chemical sciences, with a focus on analytical and catalytic pyrolysis. He has published over 80 SCI journal papers and has received more than 3,600 citations. His work is recognized in the fields of polymer and biomass pyrolysis, bio-oil hydrodeoxygenation, and microplastics analysis. He holds a prominent position in global scientific rankings for his contributions to natural and chemical sciences. His research is closely related to instrumental analysis and advancing sustainable solutions in chemical engineering.

ABSTRACT

Py-GC/MS is a highly effective technique for analyzing microplastics. This method involves the thermal degradation of microplastics at high temperatures, followed by the separation of the resulting pyrolysis products through chromatography, and their identification using mass spectrometry. Py-GC/MS provides valuable information on the types and quantities of microplastics, making it applicable across various research fields, including environmental studies, food safety, and biological samples. Before performing Py-GC/MS analysis, it is essential to carry out sample preparation steps, such as organic matter digestion or density separation, when other organic or inorganic materials are present in the sample matrix. The microplastics in the pretreated solution are then collected using filtration systems. In our research, we identified that existing filtration systems used for microplastic analysis exhibit low recovery rates, which poses a significant challenge. To address this issue, we developed a new filtration system that significantly improves the overall recovery rate. In this presentation, we will introduce our newly developed filtration system and demonstrate its application in microplastic analysis. Additionally, we will provide an overview of Microplastics analysis using Py-GC/MS, covering both the methodology and its practical applications.

Keywords: Microplastics analysis, Py-GC/MS, Filtration, Recovery

Co-authors names: Jihye Kwon, JuHye Kim, JeongHyun Kwon (Daegu University), Shogo Kumagai (Tokoku University), Atshushi Watanabe, Norio Teramae (Frontier Laboratories)

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Combined UV-Irradiation and Pyrolysis-GC/MS Approach for Evaluating the Deterioration Behavior of PV Module Encapsulant Materials

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Dr. Kumagai is an Associate professor at the Graduate School of Engineering, Tohoku University. He is working on the Journal of Analytical and Applied Pyrolysis (Elsevier) as an editor. His academic background covers the development of plastic recycling technologies and applied and analytical pyrolysis of polymeric materials. He received his Ph.D. from Tohoku University in 2015 and started his current career immediately. He was selected as one of 100 finalists in the Falling Walls Lab competition 2017 from 3,000+ candidates in 50+ countries. Dr. Kumagai has published 150+ research papers in SCI journals and 30+ reviews and book chapters.

ABSTRACT

Ethylene-vinyl acetate copolymer (EVA) is the most common encapsulation film in solar electric photovoltaic (PV) modules. EVA sheet plays an essential role in preventing the penetration of water and contaminants into solar cells. However, the ultraviolet (UV) deterioration of EVA film caused by long outdoor exposure is inevitable. It acts as a trigger of damage to the solar cell and reduction of electricity generation (Dolara et al., *IEEE J. Photovolt.*, 6, 1269 (2016), Liu et al., *Energ. Power Eng.*, 7, 348 (2015)). Therefore, understanding the UV deterioration mechanism of EVA film is vital to evaluating the operating life of PV modules, predicting the deterioration behavior of the electricity generation, and considering strategies for preventing PV module deterioration.

In this work, EVA samples were acceleratory deteriorated by employing a micro UV irradiator, UV-1047Xe (Frontier Laboratories), and the deteriorated level was evaluated by elemental analysis, Fourier transform infrared spectroscopy (FTIR), and microscopic observation. Furthermore, EVA samples with different deterioration levels were analyzed by pyrolyzer-gas chromatography/mass spectrometry (Py-GC/MS).

Long-term UV irradiation enhanced UV-induced bond cleavage and oxidation reactions, increasing in ketone and lactone groups, which are not detected in untreated samples. Various oxygen-containing pyrolysis products from UV-deteriorated samples were observed via Py-GC/MS analysis. In addition, the progress of UV deterioration lowered the onset temperature of the pyrolysis gas evolution (Yamada et al., *Polym. Degrad. Stab.*, 190, 109623 (2021)).

Keywords: PV encapsulant; Py-GC/MS; UV/Py-GC/MS; UV deterioration

Analytical Pyrolysis of Common Polymers Using Different Pyrolysis Systems: Effect of Heating Rate and Timescale on Product Distribution

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Dr. R. Vinu is currently a Professor of Chemical Engineering at IIT Madras, Chennai. He obtained Ph.D. in Chemical Engineering from Indian Institute of Science, Bangalore (2010), and was a postdoctoral researcher in Northwestern University, USA until 2012. At IIT Madras, he leads an active research group that focuses on thermochemical conversion of a diverse feedstocks such as biomass, waste plastics, algae, municipal solid wastes and low-quality coals to liquid fuels and chemicals. He is also the Director & Co-founder of the deep tech start-up company, X2Fuels & Energy Pvt. Ltd., incubated at IIT Madras Research Park, that focuses on the conversion of industrial and municipal wastes to fuels through hydrothermal liquefaction process. He has published 140+ research articles in reputed journals, 10+ book chapters, an edited book and 5 patents. He is the recipient of Young Engineer Award of the IEI, Young Scientist/Associate Awards of the INSA, NASI, IAS, ICT Mumbai, and Early Career Recognition Awards for Teaching and Research from IIT Madras. He serves as one of the Editors of Journal of Analytical and Applied Pyrolysis, and in the Editorial boards of Biomass & Bioenergy, Scientific Reports, and Frontiers in Fuels.

ABSTRACT

Analytical pyrolysis coupled with gas chromatograph/mass spectrometer (Py-GC/MS) has emerged as a promising technique for characterizing natural and synthetic polymers, and for evaluating the conversion and product distribution from a range of feedstocks from resource recovery viewpoint. Fast pyrolysis is the crux of Py-GC/MS systems. Owing to fast heating rates (≥1000 °C/s) and high sweep gas flow rates in the pyrolysis reactor, fast pyrolysis process results in high yields of condensable pyrolysate vapors, mostly the primary pyrolysis products. Understanding the kinetics and the time evolution of vapor phase species during fast pyrolysis is a challenging task, and many analytical pyrolysis devices have been used in the past to track the conversion of the sample or generation of various products at short timescales of the order of milliseconds.

We have been using different types of analytical pyrolysis reactors such as Micropyrolyzer, Pyroprobe, and Curie point pyrolyzer to understand the effect of timescale on sample conversion, pyrolysate composition and product time evolution. In this presentation, our recent investigations on analytical pyrolysis of common plastics like low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), acrylonitrile-butadiene-styrene (ABS) and polycarbonate (PC) will be discussed. The polymer samples were cryo-milled to obtain homogeneous micon-sized powders, and subjected to pyrolysis at 423, 500 and 590 °C in all three devices. Based on the heating rate, the systems can be ranked as follows: Curie point pyrolyzer > Micropyrolyzer > Pyroprobe. Polymer conversion increased with temperature in the Pyroprobe, and the máximum conversión achieved was 90% with ABS. In the case of micropyrolyzer, complete conversion of all polymers occurred. In the case of curie point pyrolyzer, the conversións achieved were similar for PP (423 °C), PS (500, 590 °C), ABS (590 °C), and LDPE (590 °C). More interesting results pertaining to the variation in product distribution and hydrocarbon composition with different pyrolysis systems will be discussed during the presentation.

Keywords: Curie point pyrolyzer; Micropyrolyzer; Polymer; Py-GC/MS; Pyroprobe

Oral Presentations

Ethanol as a Solvent for Hydrothermal Liquefaction of Palm Empty Fruit Bunch

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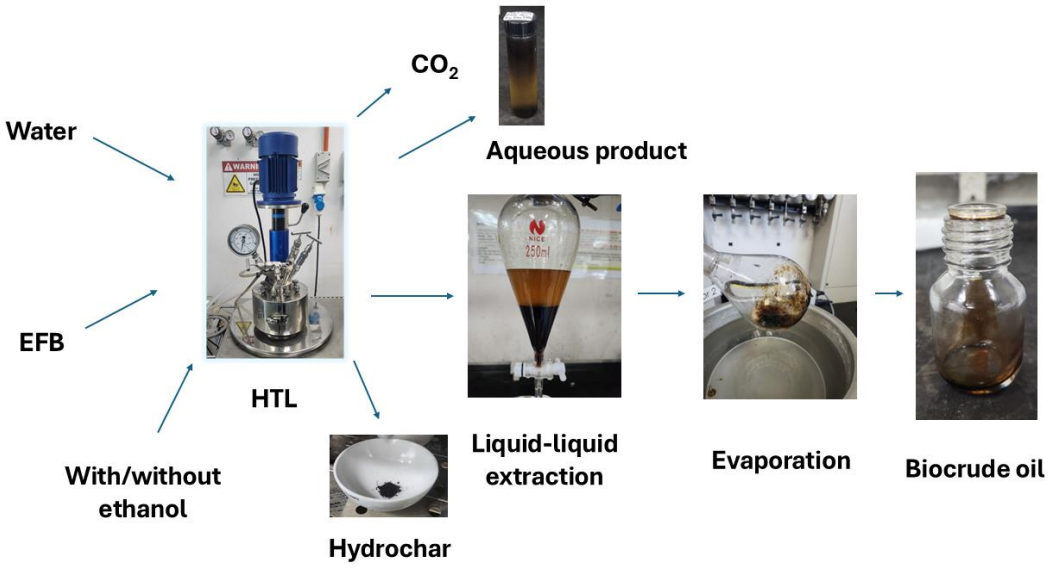
ABSTRACT

Palm empty fruit bunch (EFB) is a major byproduct of the palm oil industry that is mostly disposed through landfilling and incineration. In order to reduce the carbon emissions from the palm oil industry, novel methods for processing byproducts are required. Hydrothermal liquefaction (HTL) is a promising thermochemical process of producing biofuel that does not require an energy intensive drying step. Hydrothermal liquefaction is the thermochemical conversion of biomass into liquid fuel in hot compressed water. In this study, HTL reactions were performed in a high-pressure autoclave reactor. The required volumes of EFB, solvent, and water were inserted into the reactor which was then sealed and pressurized with nitrogen at 10 bar. The temperatures studied were 275 °C and 300 °C with and without H_2O_2. In addition, the effect of ethanol for HTL at 275 °C was studied. The concentration of ethanol varied between 20% and 100%. The highest yield obtained was 40.8 wt% at 40 wt% ethanol concentration. GC-MS, CHNS and functional group analysis were conducted for the bio crude oil. Proximate analysis was conducted on the hydrochar along with CHNS and functional group analysis. Total organic content and total phenolic content analysis were conducted on the aqueous phase.

GRAPICAL ABSTRACT (GA)



Catalytic and Non-Catalytic Pyrolysis of Walnut Shell Waste

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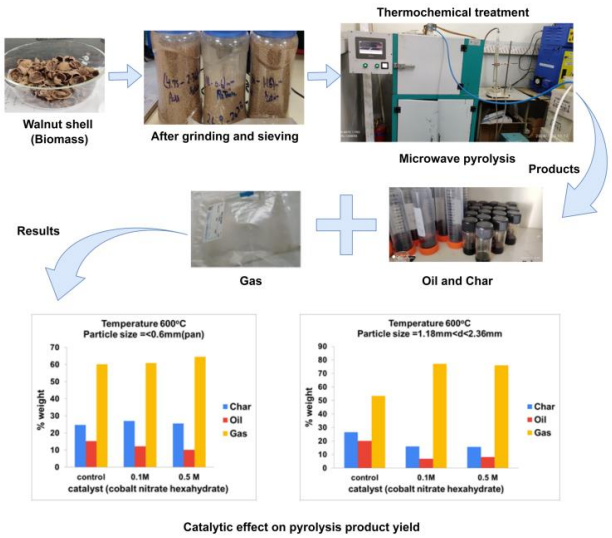
ABSTRACT

Walnut is a significant export product from the Union Territory of Jammu and Kashmir. Once the kernel is extracted, the leftover walnut shell becomes a solid waste that requires proper management. Pyrolysis presents an intriguing possibility for the utilisation of this walnut waste. For this study, a microwave pyrolysis reactor is employed to transform walnut shell biomass into valuable by products. An ultimate and proximate analysis was conducted to characterise the physicochemical properties of walnut shell. An evaluation was conducted on the conversion of walnut shell biomass waste to oil, gas and char with and without char-doped with Cobalt (metal based) catalyst in the ratio of 4:1. The catalyst was characterised using various analytical techniques, including XRD, XPS, RAMAN, SEM, EDX, TEM, and FTIR analysis. The pyrolysis oil and gas were analysed using GCMS. The pyrolysis temperature, reaction time, particle size, and sweeping gas (N_2) flow rate were adjusted within specific ranges. The temperature ranged from 400 to 600 °C, the reaction time was set at 30 minutes, the particle size varied from less than 0.6 mm to less than 4.75 mm, and the sweeping gas flow rate was maintained at 300 ml min^{-1}. The heating rate was set at 40°C min^{-1}. Maximum oil yield was obtained at 600 °C, 30 minutes, particle size range 1. d<0.6mm, catalyst doped on char in the ratio of 4:1 as 30%. Maximum gas yield was obtained at 600 °C, 30 minutes, particle size range 1.18mm<d<2.36mm, catalyst doped on char in the ratio of 4:1 as 70%.

GRAPHICAL ABSTRACT (GA)



Catalytic effect on pyrolysis product yield

Thermal Up-Cycling of XLPE Waste from Wire Industries via 7.5 TPD Pyrolysis Plant

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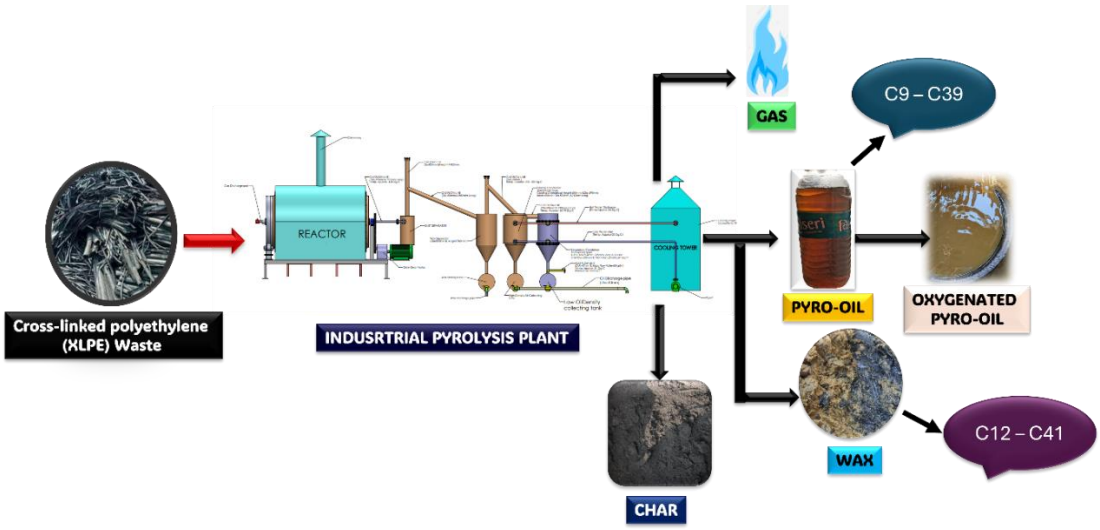
ABSTRACT

The escalating issue of cross-linked polyethylene (XLPE) waste from wire industries necessitates innovative solutions to mitigate environmental impact. This study explores the thermal up-cycling of XLPE waste using a 7.5 TPD Plant, demonstrating a sustainable approach to converting this challenging material into valuable products. Operating at 400 °C with a 6-hour residence time, the process achieved a product distribution of 35% pyrolytic oil, 40% wax, 22% gas, and 3% char. Pyrolytic oil contains C9–C39 range of hydrocarbons with a higher concentration of C10–C22, and wax, containing C12–C41 hydrocarbons focusing on C15–C32, exhibit promising characteristics for industrial fuel applications. The HHV of the pyrolytic oil and wax was found to be 51 and 48 MJ/kg, respectively. Further surface elemental analysis of char confirmed presence of C, O, Al, Cl, and Ca, respectively. This research highlights the viability of pyrolysis as a pathway for the sustainable management of XLPE waste, contributing to circular economy practices in the wire industry.

GRAPHICAL ABSTRACT (GA)



Bio-oil Production from Lipid-Rich Microalgal Biomass Grown in Open Raceway System: An Analytical Py-Gcms Study

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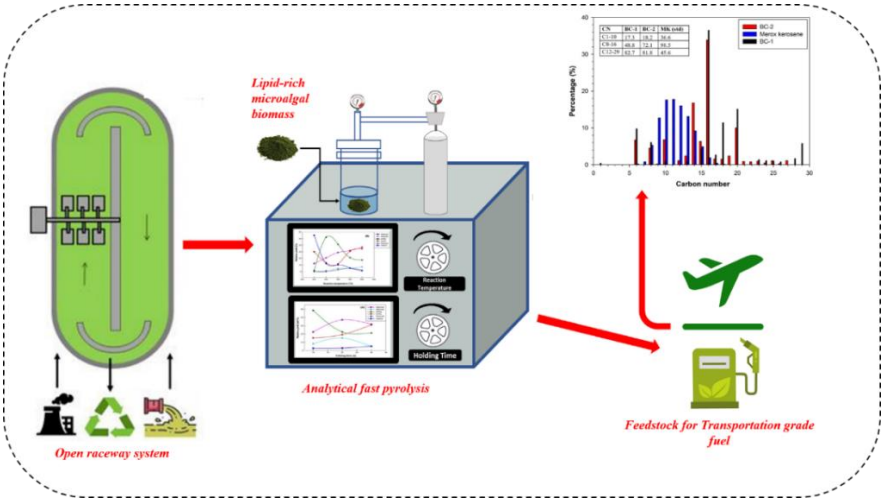
ABSTRACT

Chlorella sorokiniana (CS) biomass cultivated in open raceway system comprised of carbohydrates, proteins and most importantly high concentration of lipid, which makes it a potentially viable candidate to be used as feedstock in the production of bio-oil. The current study employs the pyrolysis process to analyze the pyrolysate composition and thermal degradation behavior of CS biomass. Firstly, thermal degradation characteristics of biomass were studied using thermogravimetric analysis (TGA). Data obtained from TGA were crucial in determining the desired reaction temperature range for pyrolysis of CS biomass. Secondly, the effect of pyrolysis parameters such as reaction temperature (RT) and holding time (HT) on the pyrolysate composition were investigated using pyrolysis-gas chromatography/mass spectrometer (Py-GC/MS). Maximum amount of condensable pyrolysis product was obtained at RT and HT of 550 ℃ and 10s, respectively. The relative yields of hydrocarbon, acids, phenols and nitrogen containing compounds under these conditions were in the range suitable for bio-oil application. Furthermore, carbon number distribution of microalgal bio-oil revealed significant proportions of kerosene (C8-16) and diesel (C12-29) precursor compounds. The findings of this study indicated that the microalgal bio-oil derived from the fast pyrolysis of CS biomass would be a promising alternative to crude oil for the production of biofuel.

GRAPHICAL ABSTRACT (GA)



Pyrolysis of Blends of Rice Husk with Bagasse and Wood Chips: Pyrolysate Composition Analysis and Distributed Activation Energy Modeling

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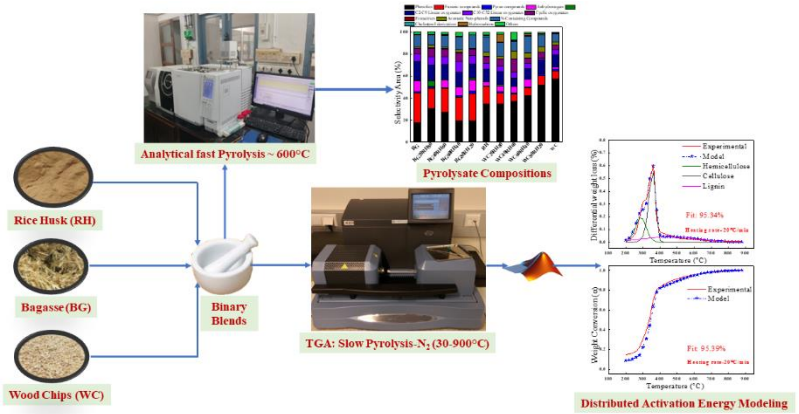
ABSTRACT

This work investigates the slow pyrolysis kinetics of three lignocellulosic biomass feedstocks, viz., rice husk (RH), bagasse (BG), wood chips (WC), and the blends of RH with BG and WC at different mixture compositions. The pyrolysis decomposition behaviour of individual biomasses and blends were evaluated using the thermogravimetric analyzer. Distributed activation energy model was developed using cellulose, hemicellulose and lignin as pseudocomponents. The activation energy for lignin decomposition was found to be greater than that for hemicellulose and cellulose. Importantly, the rate parameters for cellulose and hemicellulose were constant for all the mixtures, while the activation energy of the lignin pseudocomponent increased with increase in loading of RH in the mixture. Among all samples, RH exhibited the highest activation energy (245.4 kJ/mol) for lignin decomposition. Thermodynamic analysis showed similar observations for lignin decomposition during the pyrolysis of biomass and blend. It is hence deduced that the interactions during the pyrolysis of blends occur during lignin decomposition. The pyrolysate composition at 590 ºC was evaluated using analytical pyrolysis coupled with gas chromatograph/mass spectrometer (Py-GC/MS). The selectivity to phenolic compounds were high in WC (58.0%) followed by RH (34.7%) and BG (17.9%). For BG-RH or WC-RH blend, phenolic compounds formation retarded. For blends, significant variations in selectivity to different compounds were observed with the change in blending proportion, inferring synergistic interaction among intermediates of pyrolysates formed from individual biomass. The present investigation reveals that blending WC or BG with RH will improve the energy potential.

GRAPHICAL ABSTRACT (GA)



Co-pyrolysis of Vacuum Residue and Bio-oil: A Detailed Liquid Product Characterization

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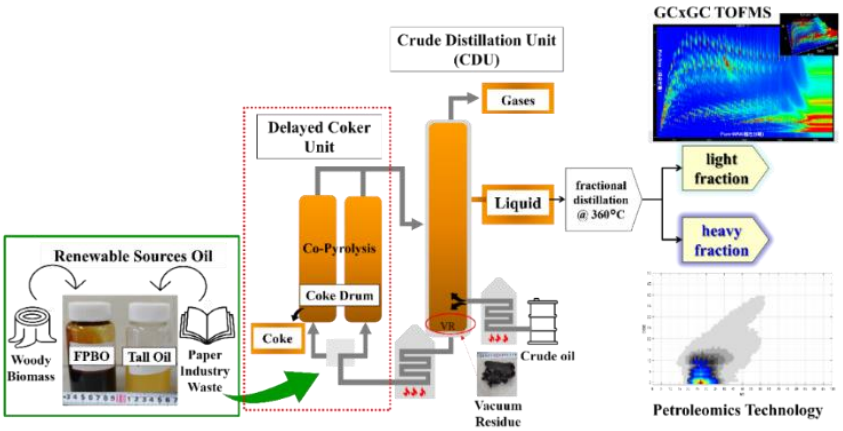
ABSTRACT

The global energy transition from fossil resources to renewables is inevitable. Integrating renewable feedstocks into the fossil fuel sector offers a practical solution for a smoother transition while maintaining energy security and promoting more sustainable industrial practices in an efficient and economical way. This research aims to blend bio-oil in a delayed coker unit, a common facility in refineries, to be co-pyrolyzed with vacuum residue (VR). In this study, VR, distilled tall oil (FA1), fast pyrolysis bio-oil (FPBO) derived from cedar wood, and mixtures of VR:FA1/FPBO (90:10 w/w) were pyrolyzed in a batch reactor, simulating a delayed coker (5 °C/min, 30 rpm (250-400 °C), 470 °C, 5-hour hold). The resulting liquid products were fractionated at 360°C. Light fractions were analyzed by GCxGC-TOFMS, and heavy fractions by Petroleomics Technology. Comparisons of the liquid product composition with VR pyrolysis alone showed that VR90_FA1 mixture had similar results to VR pyrolysis, while VR90_FPBO mixture displayed significant changes in the heavy fraction, suggesting interactions between VR and FPBO during the co-pyrolysis process.

Keywords: Bio-oil; Co-pyrolysis; GCxGC; Petroleomics; Synergistic effect; Vacuum residue

GRAPHICAL ABSTRACT (GA)



Biochar from Dried Neem Leaves and Cotton Waste: Production, Characterization and Implementation

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ABSTRACT

Agricultural wastes can be defined as the residues from the growing and processing of raw agricultural products. According to the report published by the Indian Council of Agriculture Research Institute (ICAR), it has been found that India produces more than 500 million tons (Mt) of crop residues annually. Amongst the non-fodder category, the cotton crop generates significant waste (53 Mt) with an 11% contribution in the crop residues. The agricultural wastes may be converted into valuable products or used as fuel. The efficient way to utilize agro-waste is to convert it into biochar. Biochar is an eco-friendly, carbonaceous by-product of pyrolysis**,** which is generally used for adding soil fertility, as a natural filtrate, and for other agronomical activities. In the present study, we have put a thrust on producing biochar from cotton agro-residue and dried neem leaves. The agro-waste is collected from the nearby field and sundried for two days. Using a ball mill, the size of agro-waste is reduced and screened into six different mesh sizes. Each size fraction sample is pyrolyzed in a fixed bed reactor under a Nitrogen environment to produce the biochar. The operating temperature range is maintained between 350 to 750 °C. The amount of biochar is weighed after every different operating temperature. The biochar is characterized using FTIR, XPS, FESEM & CHNS to find its applicability for soil amendment. The soil amendment has been done in a greenhouse gas environment of biochar derived from these agro-wastes to grow the tomato plant and calculating their growth parameter.

GRAPHICAL ABSTRACT (GA)

Effect of Copper on Kinetic Parameters and Pyrolysis Product Characterization of Waste Printed Circuit Board

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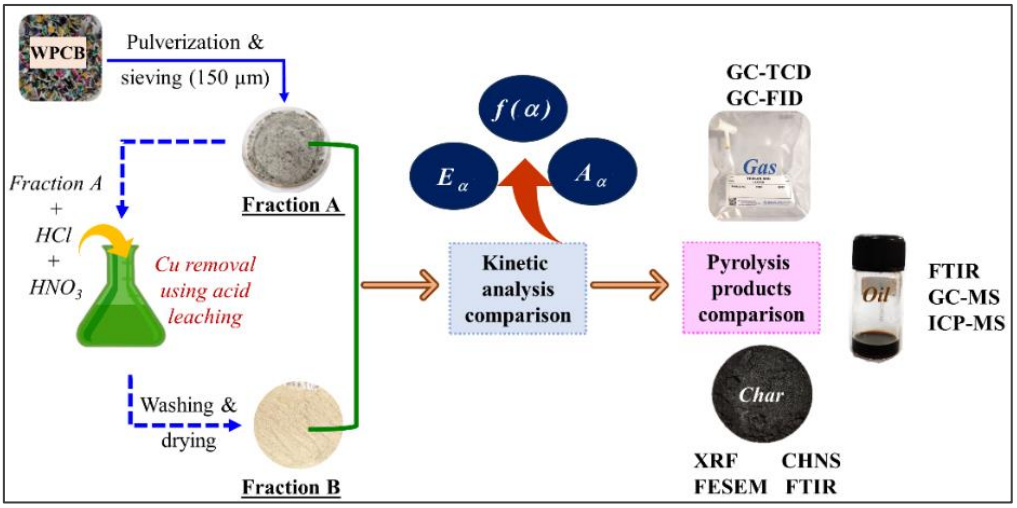
ABSTRACT

The waste printed circuit board (WPCB) contributes about 4-7 wt.% to the E-Waste stream. The presence of metals in WPCB makes it a valuable component in the waste stream, and among all the metals, copper is the most abundant. In the current study WPCB from computer system were collected, dismantled and pulverized to 150 microns. To investigate the effect of copper in the thermal degradation of WPCB, two sets of samples (A & B) were prepared. Fraction A is WPCB powder while Fraction B is acid leached WPCB using HCl and HNO_3 mixture to remove the metals. Both the samples were characterized for material and elemental compositions using proximate, CHNS, and XRF analyses. The thermal degradation behavior of the samples was analyzed by TG-DTG analysis at heating rates of 5, 10, 20 and 50 ℃/min for the temperature range of 30 – 1000 ℃ using N_2 gas. The kinetic parameters *E*, $f(\alpha)$ and *A* were determined using isoconversional methods, Criado master plot, and constable plot, respectively. The models were validated using reconstruction of conversion profiles and Starink was found to be the best fit model. The presence of copper was found to reduce the final degradation temperature by 35 ℃ (at 5 ℃/min) and average activation energy (kJ/mol) from 146.2 to 136. The $f(\alpha)$ was changed from F1 (α=0.05 to 0.5) and F2 (α=0.5 to 0.95) to F1 (α= 0.05 to 0.95). The WPCB fractions were further pyrolyzed in a lab scale semi-batch fixed bed reactor using N_2 as the carrier gas at varying operating conditions. The obtained products; char, oil and gas were subjected for detail characterization using FTIR, GC-MS, ICP-MS, CHNS, XRF, FESEM, GC-TCD and GC-FID.

GRAPHICAL ABSTRACT (GA)



Potential of Pyrolysis as an Effective Technique for Red Category Bio-Medical Waste Management

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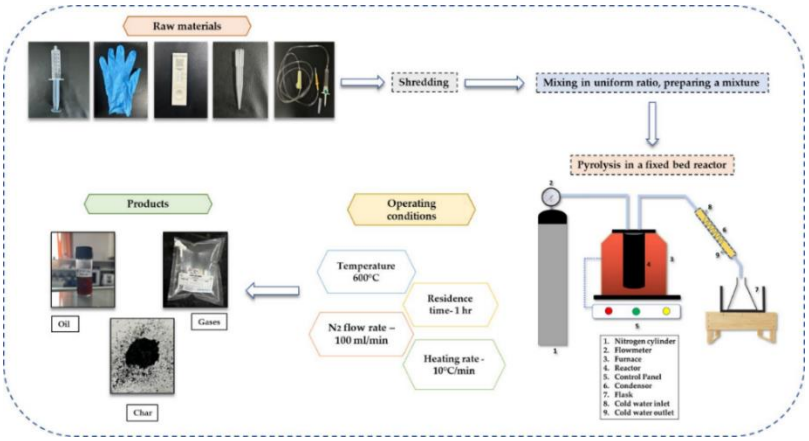
ABSTRACT

The waste generation from medical and healthcare sector is a continuous processs. When it comes to managing medical waste, pyrolysis is a relatively new process. During pyrolysis, lighter hydrocarbons are produced due to thermal decomposition of long molecule polymers, resulting in value added products which show similar properties to conventional fuel. In this work, five commonly used red category bio-medical waste items were mixed in equal proportions to prepare a mixture. The raw materials to be used for pyrolysis were characterized by ultimate analysis and thermogravimetric analysis (TGA). The data obtained from TGA can be utilized to deduce the kinetic parameters of thermal decomposition process of individual components of the medical waste as well as mixture. Further the mixture was shredded and pyrolysed at 600 ºC in a lab scale fixed bed single stage reactor with a heating rate of 10 ºC per min using nitrogen as inert gas. The obtained products were collected to estimate the yields and for detailed characterization. The yields of oil, char and gas were observed to be approximately 49%, 8%, and 42% respectively. Calorific value of oil was found to be approximately 39 MJ/Kg which is comparable to that of conventional fuels. GC-TCD analysis was conducted to analyse the composition of gaseous products such as CH_4, H_2, CO and CO_2. Whereas, long chain hydrocarbons were detected in oil by GC-FID. FTIR and NMR analysis confirmed presence of aromatics and alkanes in obtained pyrolytic oil. Performing the lab scale experiments at varying operating conditions using response surface methodology will help optimise the process to obtained the desired yield of a specific product.

Keywords: Product Characterization; Pyrolysis; Red category Bio-medical waste; Yield

GRAPHICAL ABSTRACT (GA)



Bio Oil Component Separation via Integrated Experimental and Modelling Analysis

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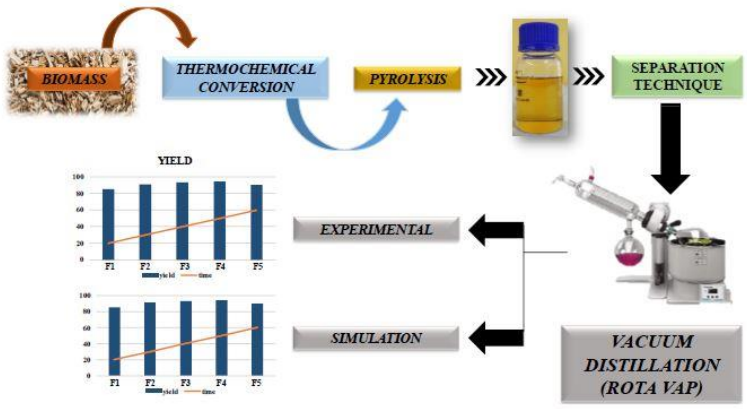
ABSTRACT

This study investigates the effect of time on the efficiency of bio-oil via vacuum distillation processes to enhance sustainable energy production. This paper reports on a study on the separation of model compounds using a combination of modelling and experimental techniques, that are indicative of mustard husk pyrolysis oil. The components included in the pyrolysis oil model are widely used in daily life and as industrial predecessors. The separation was carried out by vacuum distillation, and its findings were verified using an Aspen simulation model version 14. Experimental studies of vacuum distillation were carried out using rota vacuum evaporator with a thorough investigation of duration variation ranging from 20 to 60 minutes, at temperatures 80–90 °C and 90 mbar and 50 mbar vacuum pressures. An analysis was conducted on the distillate and residue and its recovery was calculated. It had a distillate yield of 31% and 62% for lighter fractions. The simulated feed combination mimicked the composition of bio-oil and included phenolic, acids, furfurals, furan methanol, and water. The study revealed that optimizing time significantly improved separation yield by 8% from 20 to 40 minutes, but yield started to decline after 40 minutes. When the mass balance of the feed and recovered fractions was examined, less extraneous components were discovered in the residual phase and none in the distillate phase. These findings contribute to the development of more efficient bio-oil distillation techniques, with potential applications in the renewable energy sector.

GRAPHICAL ABSTRACT (GA)



Synergistic Catalytic Insights: Noble Metals Supported on Ni-based Perovskite Catalysts for Enhanced Hydrodeoxygenation of Guaiacol

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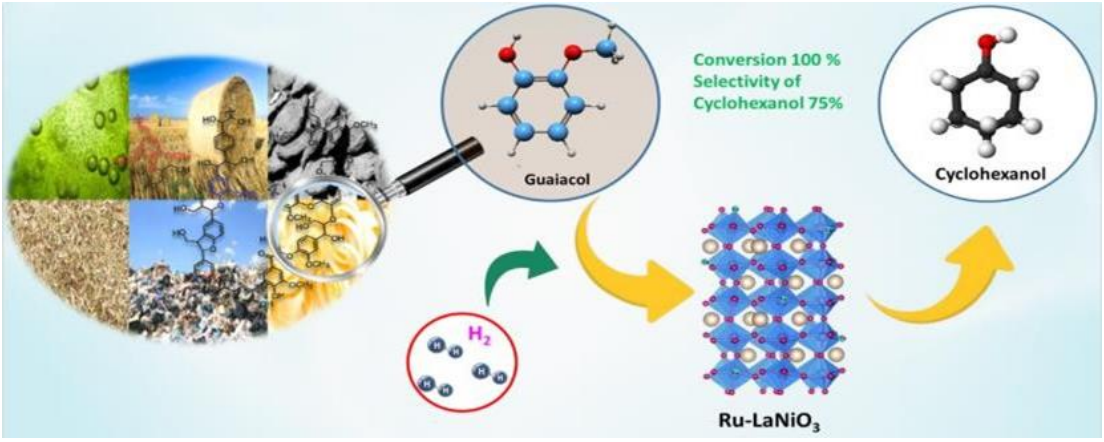
ABSTRACT

The utilization of biomass resources is one of the most pressing global concerns for sustainable and green chemistry. Herein, we have fabricated Ni based perovskite catalysts ($LaNiO_3$ and $NiTiO_3$) by sol-gel method followed by combustion by using citric acid. In this study, we showcased noble metal doped perovskite, comprising basic $LaNiO_3$ and acidic $NiTiO_3$ catalysts for guaiacol hydrodeoxygenation (HDO). The findings show that Ru-$LaNiO_3$ catalysts show better cyclohexanol selectivity (75%) with 100% conversion, while $NiTiO_3$ shows only 43% conversion and poorer cyclohexanol selectivity (25%) at 240 °C, 30 bar H_2, 4h. In comparison to $NiTiO_3$-supported catalysts, the HR-TEM investigation shows that nickel nanoparticle size was small and metal dispersion was high over $LaNiO_3$. The XPS results suggest that, compared to $NiTiO_3$, the reduction of nickel and noble metal over $LaNiO_3$ was easier, which may be because of the strong contact between Ni and Ti. The XPS O 1s spectra of Ru-$LaNiO_3$ spectra reveal a lower abundance of oxygen vacancies (O_{Vac}) ~21% and a higher amount of lattice oxygen (O_{Lat}) ~79% when compared to the other catalyst system. This result points out that a certain ratio of O_{Lat}/O_{vac} is required for the HDO of guaiacol. According to the In-situ DRIFT investigation, the Ru- $LaNiO_3$ catalysts exhibit a greater HDO reaction rate than the Ru-$NiTiO_3$ catalyst and their selectivity for cyclohexanol from guaiacol is controlled by the keto-enol tautomerization pathway. This comparative studies reveals that role of oxygen vacancies, metal dispersion, metal –metal oxides interphase is key responsible for the HDO of bio oil model compounds.

GRAPHICAL ABSTRACT (GA)



Comprehensive Characterization and Passivation Strategies of Biochar for Safe Storage Stability

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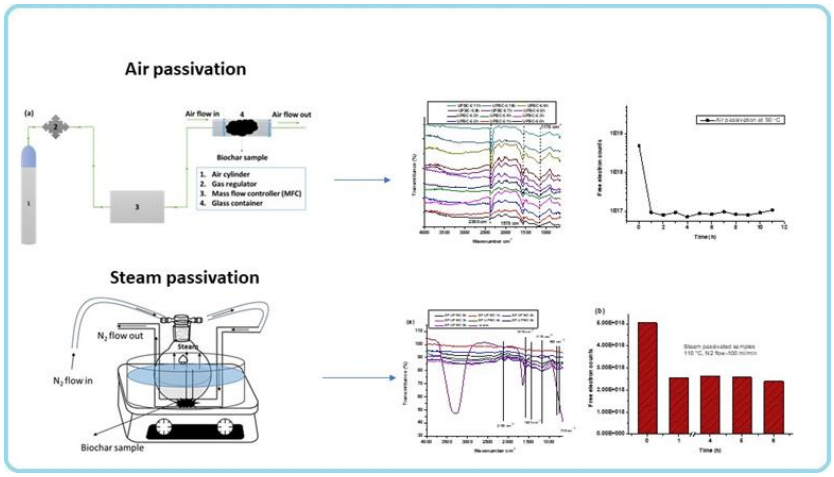
ABSTRACT

Biochar has emerged as a promising alternative carbon and fuel source within the process industry and energy sector, offering a sustainable substitute for conventional coal. Biochar, produced via the hydropyrolysis of biomass using Shell's process, exhibits significant reactivity when exposed to air, leading to exothermic reactions that pose a risk of spontaneous ignition. Preliminary storage experiments in containment bins have shown temperature rises as high as 70 °C, highlighting the critical need for continuous monitoring to prevent self-heating and runaway reactions. This presents important safety considerations for biochar storage and transport, particularly during the scale-up of production in demonstration plants with capacities of approximately 1,500 kg/day, or in commercial plants with outputs reaching up to 250 tons/day. To mitigate self-heating, traditional practices such as material cooling, periodic mixing, and oxygen-free storage have been employed. However, to optimize storage safety, a comprehensive characterization of different biochar samples is essential for developing effective passivation strategies. In this study, air and steam passivation techniques were applied to untreated biochar samples provided by the Shell Technology Center. These methodsprovided valuable insights into the effectiveness of passivation using different agents, such asair and steam. Pre-passivation and post-passivation, the biochar samples were analyzed using Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance (FTIR-ATR), Electron Spin Resonance (ESR), and Differential Scanning Calorimetry (DSC) to qualitatively and quantitatively assess the passivation processes.

GRAPHICAL ABSTRACT (GA)



Multi-Target Prediction of Biochar Yield and HHV Using Ensemble of Decision Trees

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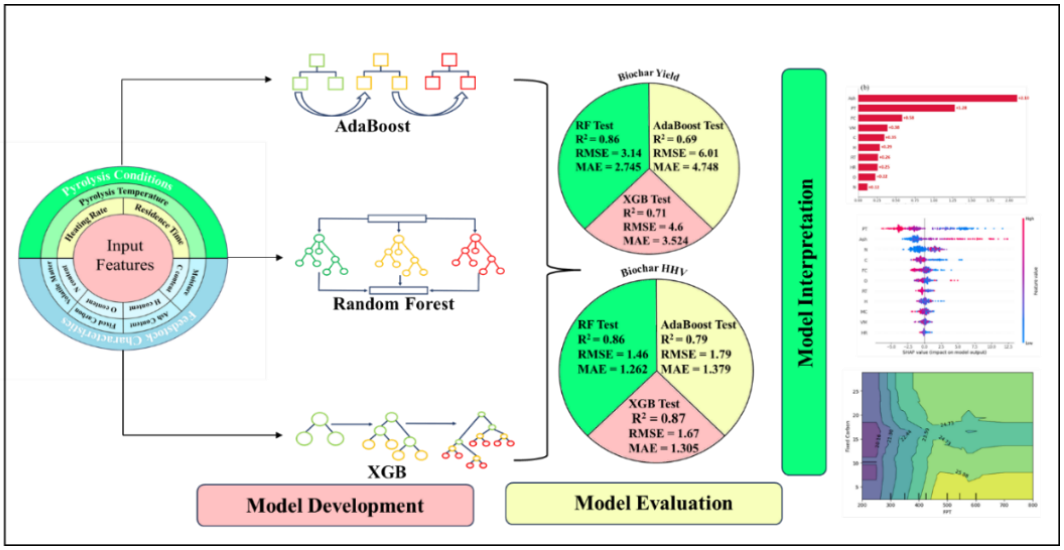
ABSTRACT

Machine learning (ML) techniques are being extensively explored to model the complex pyrolysis process. While the focus has been on assessing performance of various ML models to predict biochar yield and properties, less attention has been given to quality and comprehensiveness of the data fed to these ML models. A comparatively larger dataset of biochar yield and higher heating value (HHV), comprising 423 and 191 observations from 44 different biomasses, respectively, was curated from peer-reviewed journals. Stratified shuffle split was employed to effectively manage the limited data available during model development. This method yielded more accurate results compared to the conventional random splitting of the dataset. Three prominent ensemble learning methods, viz. Random Forest (RF), eXtreme Gradient Boosting (XGB), and Adaptive Boosting (AdaBoost) were utilized to develop predictive ML models. RF regressor achieved a test R^2 of 0.86 for biochar yield, while XGB regressor achieved a test R^2 of 0.87 for biochar HHV prediction. The SHapley Additive exPlanations (SHAP) analysis revealed that pyrolysis temperature and ash content of the biomass were the most influential features for predicting both the yield and HHV of biochar. The partial dependence plots revealed nonlinear relationships, interpreting how the ML model formulates its predictions.

Keywords: Biochar yield; Ensemble learning; Higher heating value; Machine learning; Pyrolysis

GRAPHICAL ABSTRACT (GA)



Recovery Potential of Plastics and Plastic Blends Through Catalytic and Non-Catalytic Pyrolysis: A Comparative Study Using Analytical Pyrolysis Techniques

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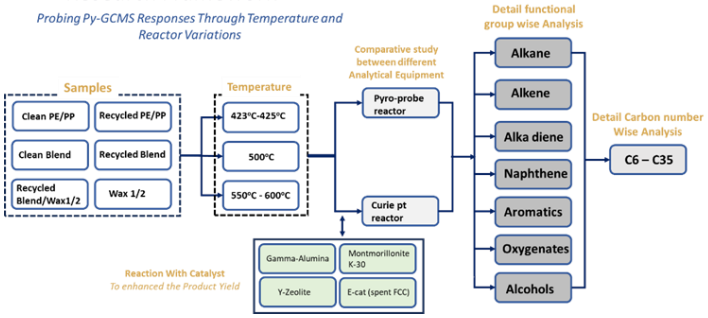
ABSTRACT

The global apex of plastic waste generation necessitates urgent, eco-friendly solutions. Thermo-catalytic strategies emerge as promising avenues to combat plastic pollution while yielding valuable products such as fuel blends or refinery blend stocks. This study meticulously evaluates the resource recovery potential of pyrolysis of recycled plastics (primarily PE and PP), individually and in mixtures, with and without catalysts. Additionally, it presents a comparative analysis of two analytical pyrolyzer techniques: pyro-probe (resistance-based heating) and Curie point pyrolyzer (induction-based heating). Comprehensive physicochemical characterization of the plastics was conducted using advanced analytical tools, including elemental analysis, thermogravimetry, differential scanning calorimetry, and ATR-FTIR. Pyrolysis experiments were performed within a temperature range of 423 °C to 600 °C in both pyrolyzers. Notably, the Curie-point pyrolyzer exhibited superior plastic conversion and monomer yields compared to the pyro-probe. The vapors predominantly contained alkenes at lower temperatures, followed by naphthene and alkanes. Furthermore, the pyrolysate from recycled feedstocks and wax in both pyrolyzers indicated the presence of oxygenated compounds, such as 2-hexyl-1-Decanol (5%), while >C20 (Heneicosane (10%)) was observed in the Curie-point pyrolyzer for both polymers and their blends. Catalytic pyrolysis using Gamma-Alumina demonstrated high selectivity for alkanes, increasing from 30% in non-catalytic pyrolysis to 64% in catalytic pyrolysis. This drastic reduction in alkadiene selectivity suggests the promotion of secondary hydrogenation reactions, yielding high alkane selectivity. Additional intriguing observations and results concerning the effects of other catalysts (e.g., Montmorillonite K-30, Y-Zeolite, E-cat (spent FCC)) and selectivity towards desired fuel-grade compounds will be discussed during the presentation. In summary, this work establishes a robust foundation for the effective utilization of plastic wastes through catalytic pyrolysis.

GRAPHICAL ABSTRACT (GA)



Production of Renewable Liquid Oil from Pistachio Shells and Low-Density Polyethylene Through Co-Pyrolysis

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ABSTRACT

Disposal of waste plastic faces challenges due to non-biodegradability; leading to landfill accumulation. On the contrary, pyrolysis is a viable process for converting waste plastic into valuable components such as liquid oil and carbon-rich solid char for efficient disposal and resource recovery. This approach can improve economic feasibility, reduce landfill usage, lower greenhouse gas emissions, and advance renewable energy development. Additionally, solid waste also consists of waste biomass such as agricultural or forest residue which also needs to be used as a feedstock to discourage stubble burning. Thus, the present study explores the co-pyrolysis of waste LDPE (curd and milk pouches), and waste biomass (pistachio shells), in a fixed-bed batch reactor to produce liquid fuel. The waste plastic and biomass feed was varied in three different ratios (1:1, 2:1, and 3:1) and experiments were performed at 450-650 °C at a heating rate of 20 °C/min. Different characterization techniques such as ultimate, proximate, thermogravimetric, and FTIR analyses were used to analyse the feed mixture and obtained product for hypothesizing a plausible reaction mechanism. It was observed that the presence of minimal moisture with high volatile matter content in the feed mixture ascertained the maximum quantity of liquid oil. A minimal amount of solid residue and non-condensable gases further confirmed the efficiency of the selected process.

Keywords: Co-pyrolysis; Proximate analysis; Thermogravimetric analysis; Ultimate analysis; Waste low-density polyethylene; Waste pistachio shells

GRAPHICAL ABSTRACT (GA)

Pyrolysis-Engineered RDF Char: Enhancing Fixed Bed Column Performance

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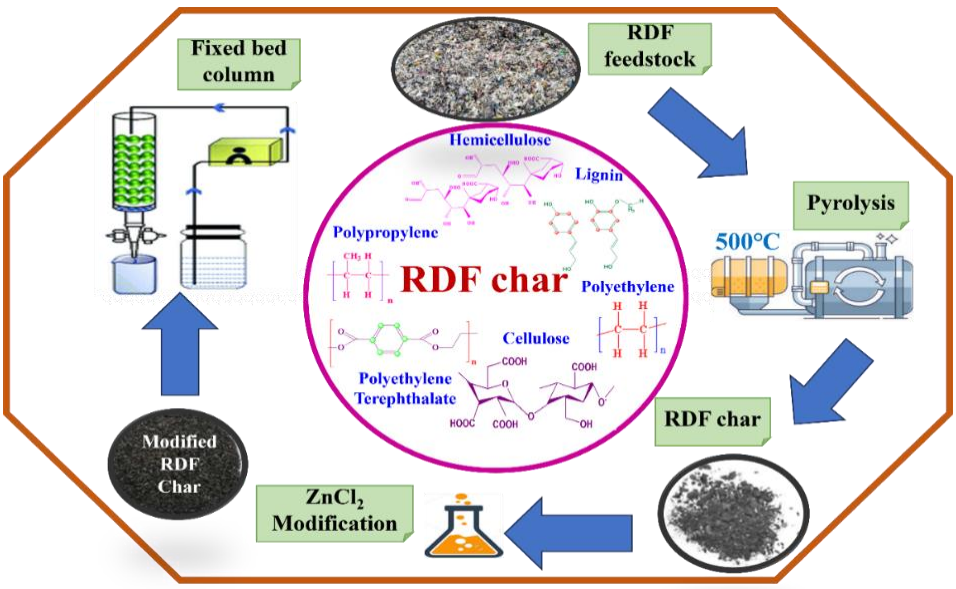
ABSTRACT

This study investigates the potential of engineered refuse-derived fuel (RDF) char as an adsorbent in a afixed bed column, produced at 500 ℃ through a customized rotary kiln pilot-scale pyrolysis reactor for removal of nitrate (model pollutant), addressing the dual challenges of waste management and water treatment. The breakthrough curves were predicted by varying bed height (7.5 to 15 cm), initial adsorbate concnetration (150-350 mg/L) and flow rate (1-5 mL/min) and model fitting by Thomas, Adams-Bohart, and Yoon-Nelson models to the experimental data. Results demonstrated that RDF char exhibited promising adsorption capacity of 160 mg/g, after chemical modification with zinc chloride in weight ratio 2:1 (zinc chloride:char). Adsorption phenomena was influenced by the surface area, solution pH, functional groups and net charge of the char. Significant variablity in performance was observed due to the heterogeneous nature of the Municipal solid waste (MSW) derived RDF feedstock. Future work should focus on enhancing the consistency of RDF char characteristics and further exploring its efficacy in treating real world and complex effluents for scale-up sustainably.

Keywords: Adsorption; Fxed-bed column; Nitrate; Pyrolysis; RDF char

GRAPHICAL ABSTRACT (GA)



Solid Carbon and Hydrogen Production by Methane Pyrolysis Using Non-Thermal Plasma

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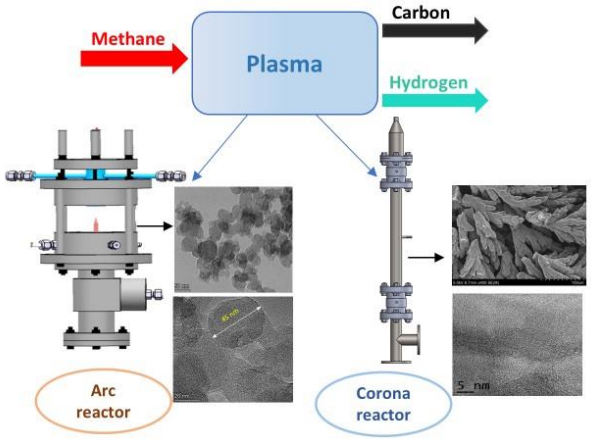
ABSTRACT

Methane cracking by non-thermal plasma (NTP) is a state of the art process used to produce pure hydrogen, a potential energy carrier for the future and commercially valuable solid carbon. This study used two different reactors corresponding to two different types of non-thermal plasma discharges for the methane cracking process namely, 1) swirl-induced rotating arc discharge reactor, 2) coaxial cylindrical corona discharge reactor. The swirl-induced rotating arc discharge reactor uses arc discharge to decompose methane whereas the coaxial cylindrical corona discharge reactor uses corona discharge. Although both the discharges yield the same products, there are major differences in the mechanism, physical conditions of the process, and morphology of the carbon produced. Both the reactors used the same high voltage-high frequency power supply and the process was conducted with 50-70 W power input at 19kHz frequency. From the arc discharge reactor hydrogen was obtained as the major gaseous product at 16%, and hydrocarbons like acetylene and ethane were present in minor quantities. Selectivity of hydrogen was 84% with highest methane conversion of 19.7% at 0.5 L/min flow rate of methane and input power of 55 W. A maximum temperature of 130°C was observed by performing Thermographic analysis during the reaction, this low temperature poses an advantage eliminating the need for external cooling methods. The carbon morphology was characterized using electron microscopy and Raman spectroscopy, which shower irregular aggregate structure of highly pure carbon (~96%). Thermogravimetric analysis results show that the Carbon has high thermal stability.

GRAPHICAL ABSTRACT (GA)



A Comparative Study of Bio-Oil Production Via Two-Stage and Direct Hydrothermal Liquefaction Process from Microalgae Grown on Dairy Wastewater

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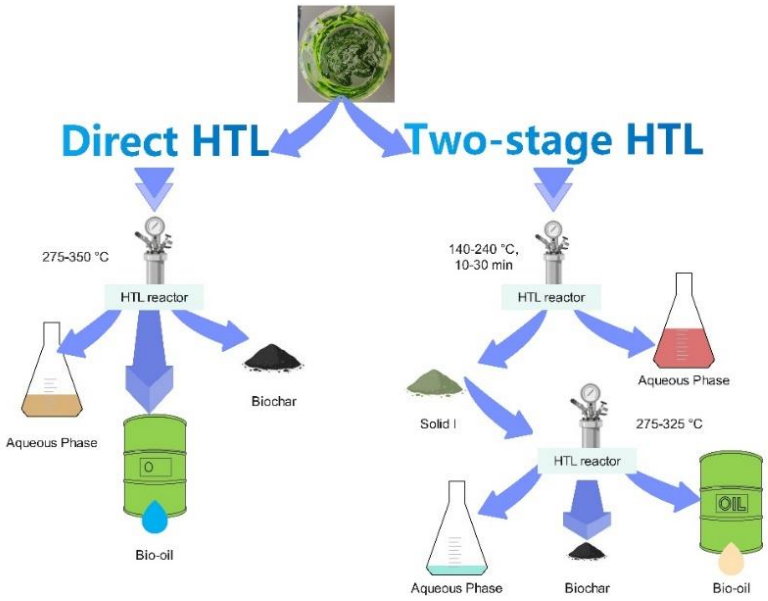
ABSTRACT

Hydrothermal liquefaction technology is an approach that can be employed to produce energy resources from potential algal feedstock. Nevertheless, the practical utilization of bio-oil is impeded by the high nitrogen and oxygen content in wastewater-grown microalgae, which results in the presence of many heteroatoms. The elemental composition and yield of the bio-oil produced through direct high-temperature liquefaction and two-stage hydrothermal liquefaction were compared in this study. Direct hydrothermal liquefaction yielded a bio-oil yield of 33.5 wt%, with a high proportion of N/C, H/C, and O/C. The two-stage hydrothermal liquefaction process was employed to enhance the H/C and decrease the N/C of the feedstock, thereby increasing the H/C atomic ratio and reducing the N/C and O/C ratio of bio-oil. The technology mentioned above achieved superior bio-oil quality by extracting carbohydrates and protein components from algae biomass at lower pretreatment temperatures earlier. The elemental analysis of bio-oil obtained from two-stage hydrothermal liquefaction was consistent with the GC-MS results. The quality of the bio-oil obtained from pre-treated phytoplankton through two-stage HTL was enhanced, as evidenced by reduced levels of N-heterocyclic compounds and elemental analysis. The bio-oil quality was greatly enhanced by the results of the two-stage hydrothermal liquefaction process, without a decrease in yield.

GRAPHICAL ABSTRACT (GA)



Conversion of Lignocellulosic Biomass to 5-HMF Over Bifunctional Metal-Loaded Biochar Catalyst With Biphasic Solvent

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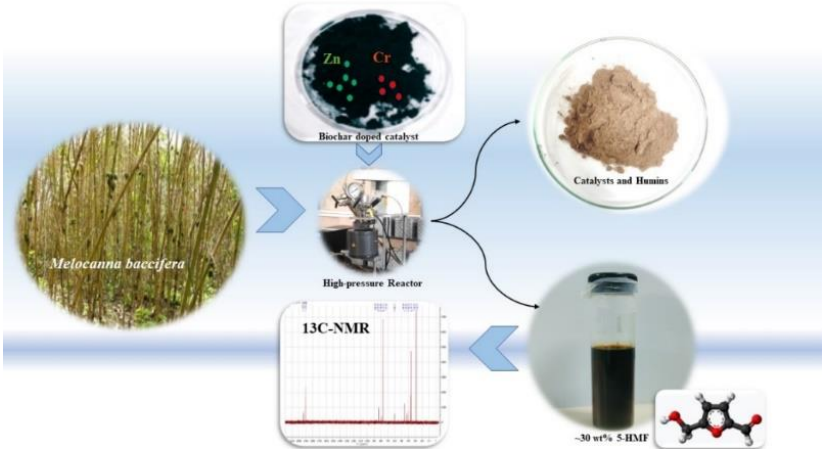
ABSTRACT

Lignocellulosic biomass feedstocks were enormously explored for manufacturing important products such as biofuels, commodity chemicals, and new bio-based materials. In this work, the biochar produced was loaded with bifunctional catalyst metals (Zinc or Chromium) and *p*-toluene sulfonic acid used to produce 5-HMF and biphasic organic solvents were used as a solvent. The cellulosic part of the biomass was depolymerized into glucose in the presence of a biphasic solvent (MIBK/water). Further, bifunctional catalysts were provided at the Bronsted and Lewis acid site which was helpful in the production of 5-HMF. The structure, texture, pore size distribution, electronic state, and acidity of the synthesized catalysts were assessed using a range of analytical methods, including X-ray diffraction, energy dispersive spectroscopy, field emission scanning electron microscopy, thermogravimetric analysis, Brunauer Emmett Teller, and Fourier-transform infrared spectroscopy. The steps involved during lignocellulose biomass to 5-HMF production are hydrolysis of cellulose into glucose, isomerization of glucose into fructose, and dehydration of fructose into HMF. During the reaction process of 5-HMF production, the yield can be increased by increasing the concentration of the Bronsted acid site. The yield variation of 5- HMF is in the range of 30 - 40% of the lignocellulosic biomass. A high-pressure high-temperature autoclave reactor was used and the operating temperature was varied between 180 ℃ to 220 ℃ along with residence time between 15 min to 2 h. Further, 5-HMF reacts in an aqueous mixture with two water molecules, forming levulinic and formic acids.

Keywords: Bifunctional catalyst; Biochar; Catalyst, HMF; Lignocellulosic biomass

GRAPHICAL ABSTRACT (GA)



Recovery of Petrochemicals from Oxygenated Aromatic Plastic Wastes Using Red Mud via Thermo-catalytic Depolymerization

Subhan Kumar Pal[1], Vallabh S. Prabhudesai[1], Kaustubha Mohanty[2], Vinu R[1*]

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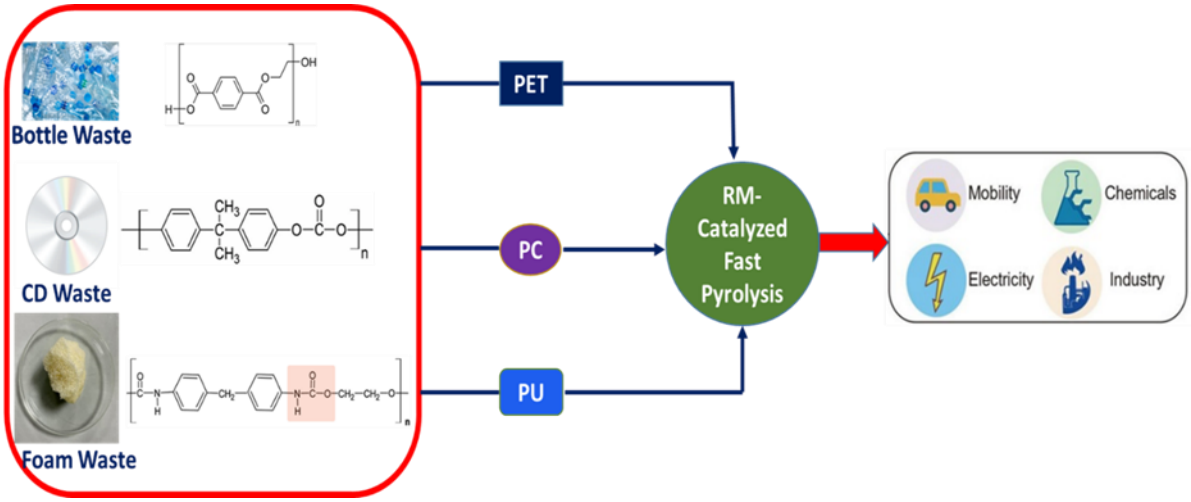
ABSTRACT

The increased rate of post-use accumulation of the heteroatom-containing plastic wastes like polyethylene terephthalate (PET), polycarbonate (PC) and polyurethane (PU) in the environment propels the research for effective and sustainable valorization. In this study, PET from bottle waste, PC from compact discs and PU from waste wind turbine blade were characterized and employed for fast pyrolysis experiments. Importantly, red mud (RM), a mixed oxide, rich in Fe, Al, Si, Na and Ca, was used as a catalyst for fast pyrolysis. The effects of temperature and feed-to-catalyst ratio on product yields were studied to elucidate the product formation mechanism. Benzoic acid and its derivatives, bisphenol-A and oxygenated aromatics, and 4,4'-methylenebisbenzamine were the major products obtained from the non-catalytic fast pyrolysis of PET, PC and PU, respectively. The use of RM improved the yield of aromatic hydrocarbons from PET to 27.8 wt.% at 550 °C, phenolics from PC to 46.6 wt.% at 550 °C, and 4,4'-methylenebisbenzamine to 34.9 wt.% at 650 °C. The catalytic activity of RM is ascribed to the presence of active basic sites. The present study paves the path for the catalytic upcycling of challenging plastic wastes using industrial waste like RM as a sustainable catalyst from a circular economy viewpoint.

GRAPHICAL ABSTRACT (GA)



Catalytic Hydrodeoxygenation of Co-Pyrolytic Oil Produced from Nahar Seeds and PET Plastic

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ABSTRACT

The present study investigates the catalytic hydrodeoxygenation (HDO) of bio-oil produced via co-pyrolysis of Mesua ferrea L. (Nahar, a non-edible oilseed) and PET plastic. Operating parameters, including temperature and biomass-to-plastic ratio, were optimized, yielding a maximum bio-oil production of 35 wt.% at 873 K with a 2:1 feedstock ratio. The bio-oil composition was dominated by fatty and carboxylic acids (~55%), necessitating upgrading for practical applications. Red mud (RM), a byproduct of alumina production, was used as a support material for mono (Ni) and bi-metallic (Ni-Co, Ni-Mo) catalysts, with nickel content at 5 wt.%. These catalysts were characterized using advanced techniques such as FESEM-EDX, FETEM, XRD, ICP-MS, XPS, and surface area analysis. HDO experiments demonstrated that bi-metallic catalysts significantly enhanced the PIONA fraction (paraffins, isoparaffins, olefins, naphthenes, aromatics). The Ni-Co/RM catalyst yielded the highest organic liquid product (72%) with reduced coke formation and a hydrocarbon yield of 80%. Upgraded oil exhibited an oxygen content below 2 wt.% and a reduction in acidity from ~55% to ~2%. The main reaction pathways included hydrodeoxygenation (HDO) and decarboxylation (DCO). Overall, applying Ni (10 wt.%), Ni-Co, and Ni-Mo supported RM catalysts effectively improved bio-oil upgrading and hydrocarbon yield.

GRAPHICAL ABSTRACT (GA)

Tailoring Hydrothermal Liquefaction (HTL) for Pioneering Green Process to Valorize Biomass Waste into High-value Products

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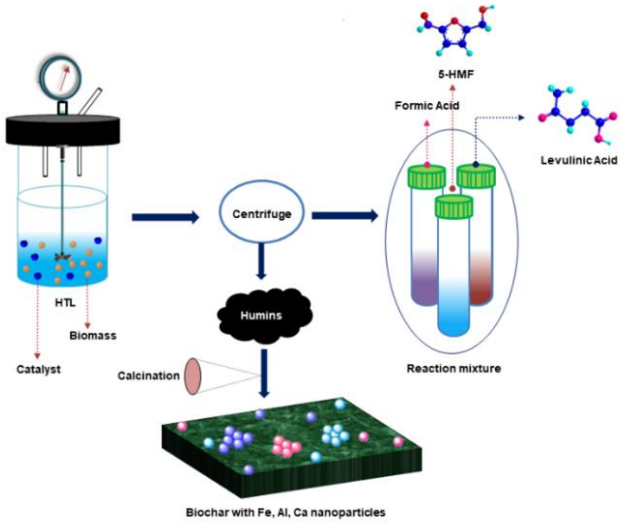
ABSTRACT

In current trends, transforming solid waste biomass into high-value fuels and chemicals can uplift the world's energy landscape and will be a panacea for rapid socio-economic development. One of the most promising biomass-derived platform chemicals with an amplified perspective for producing various downstream commodities is levulinic acid (LA) containing ketone and a carboxylic acid group. Instead of utilizing an expensive substrate, this study particularly concentrated on a novel and adaptable second-generation biomass waste to produce LA. The study considered lignocellulosic biomass known as *Luffa cylindrica*, which is widely available in the northeastern Indian states of Assam, Manipur, Arunachal Pradesh, etc. A series of comprehensive analytical techniques were tested as a way of determining the potential of Luffa for the production of LA. A lucrative conversion of Luffa to LA was carried out under the influence of $CaCl_2$, $ZnCl_2$, $FeCl_3$ and $AlCl_3$ using hydrothermal liquefaction (HTL). An optimistic approach produced a maximum LA with a 38.2% yield and BM conversion of 80.5% at 220 °C, 30 min and 0.045M $AlCl_3$. The yield of levulinic acid in the aqueous phase without a catalyst and solvent was estimated at a very low quantity (12.62%). The lack of sufficient Bronsted-Lewis dual-acid sites and the poor stability of hydroxyl methyl furfural (HMF) are responsible for hindering selectivity and conversion. Further characterization of the $AlCl_3$-catalyzed HTL-derived liquid phase was carried out by addressing one-dimensional ^1H NMR analysis and Liquid chromatography inductively coupled plasma mass spectrometry (LC-ICPMS).

GRAPHICAL ABSTRACT (GA)



Optimization of Pyrolysis Parameters for Biochar Production from Kodo Millet (*Paspalum Scrobiculatum*) Husk and Characterization of the Product as a Precursor for Activated Carbon

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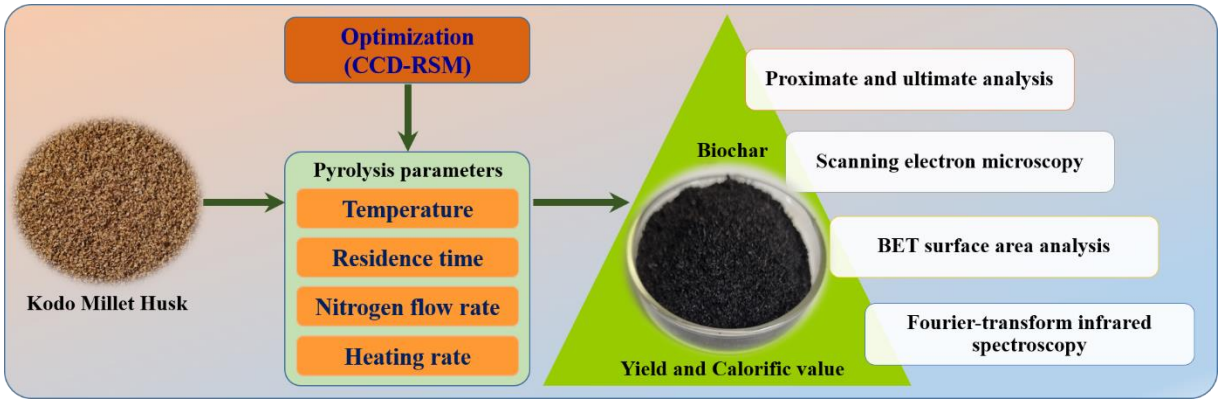
ABSTRACT

This study aimed to optimize the pyrolysis parameters for biochar production from kodo millet husk using response surface methodology (RSM) based on the central composite design (CCD). Critical process parameters of pyrolysis, such as temperatures, residence time, N_2 flow, and heating rates, are varied in the range of 450–650 °C, 1–3 h, 100–500 cc/min, and 5–25 °C/min, respectively. The influence of process parameters on biochar recovery and higher heating value (HHV) was studied. The optimized biochar was thoroughly characterized using techniques such as proximate and ultimate analysis, scanning electron microscopy (SEM), Brunauer–Emmett–Teller (BET) surface area analysis, and Fourier-transform infrared spectroscopy (FTIR). The optimized biochar exhibited desirable properties, including high carbon content, favorable porosity, and surface functionality, making it a suitable precursor for further activation. The findings of this study demonstrate that kodo millet husk can serve as a valuable feedstock for biochar production, and the resulting biochar exhibits promising characteristics for subsequent activated carbon synthesis. This research contributes to the sustainable utilization of agricultural residues and provides insights into optimizing pyrolysis parameters for biochar production.

Keywords: Biochar; Material characterization; Millet husk; Optimization; Pyrolysis

GRAPHICAL ABSTRACT (GA)



Multi-parameter Optimization and Predictive Modeling of Pyrolysis of Walnut Shells Using Response Surface Methodology and Machine Learning Algorithms

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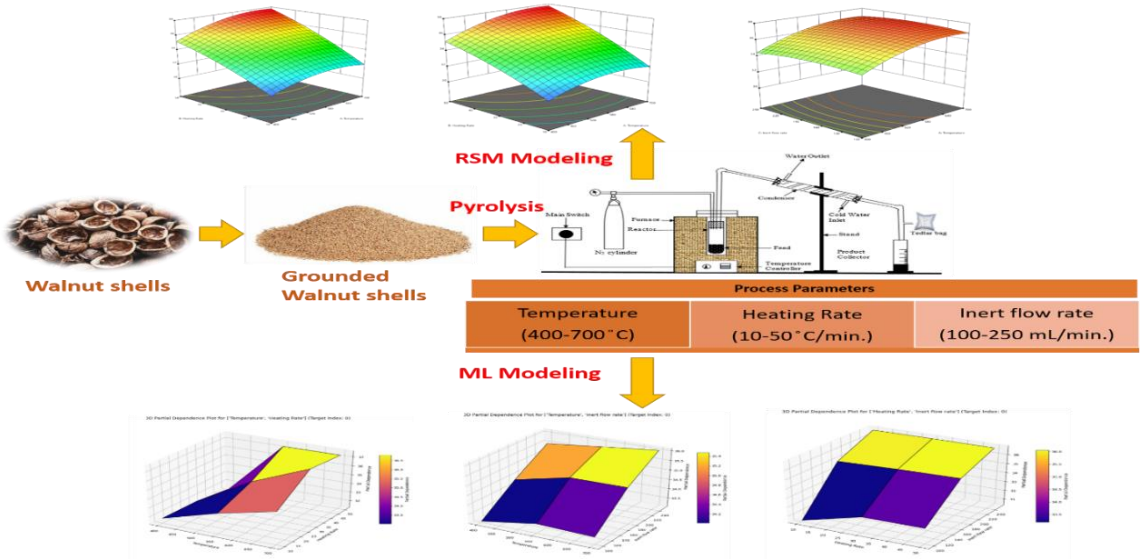
ABSTRACT

The present study focuses on optimizing the pyrolysis of walnut shell, examining the influence of key process parameters (temperature, heating rate and inert flow rate) on the bio-oil and bio-char yield. Integrated approach of response surface methodology (R^2 = 0.92), XGboost (R^2 = 0.99) and Decision tree (R^2 = 0.74) demonstrated a higher prediction accuracy and lower error margins. Experimental bio-oil yield (37.32%) was obtained at optimized parameters (692.47 °C temperature, 49.93 °C/min. heating rate and 238.30 ml/min. inert gas flow rate) was compared with bio-oil yield predicted from response surface methodology (37.57%), XGBoost (35.17%) and Decision tree (37.56%). GC-MS and FTIR techniques highlighted that the bio-oil was composed of various organic compounds and can be an alternative of hydrocarbon fuels after some upgradation. Various industrial chemicals can also be extracted from the bio-oil. Higher heating value of bio-char obtained at optimized condition was 24.62 MJ/kg, which can be as used as bio-coal. The study showed that walnut shells can be effectively valorized through pyrolysis process for the production of sustainable bioenergy while reducing reliance on fossil fuels and promoting sustainable resource management.

GRAPHICAL ABSTRACT (GA)



Pyrolyzed Rubber Wood Biochar as a Soil Amendment Agent: Impact on Water Retention and Okra Yield in Smart Irrigation Systems

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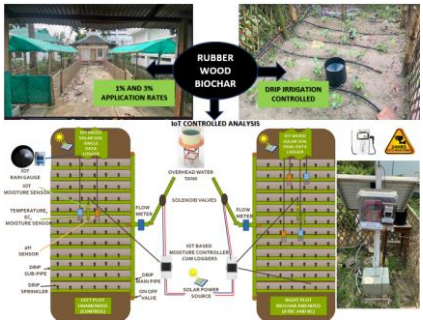
ABSTRACT

This study presents a comparative analysis of rubber wood biochar samples produced using two distinct pyrolytic processes: one acid-treated and the other untreated, both conducted at temperatures exceeding 500 °C with an objective of exhibition of superior water retention properties aimed for agricultural applications. The water-holding capacity of the samples was evaluated over a 72-hour period, along with their evaporation characteristics. These biochars were subsequently incorporated into soil at 1% and 3% ratios to assess their efficacy as soil amendments. Various analytical techniques, including proximate, ultimate, and compositional analyses, were performed on the rubber wood feedstocks and its derived biochar samples. Characterization methods such as BET, FESEM, and PSA were also employed. The acid-treated biochar when compared to the untreated biochar was specifically designed to enhance porosity and water retention properties. An experimental study was conducted with okra plants from May to August 2024, utilizing an in-house developed IoT-controlled solar drip irrigation system. Soil and atmospheric conditions were continuously monitored. The results indicated that 3% acid-treated biochar (ATBC) prepared at 700 °C yielded optimal plant growth and okra production, both in water-abundant and water-scarce conditions. The study concludes that biochar, particularly acid-treated modified biochar can be used to enhance soil water retention property, organic carbon content, and reduces soil bulk density, providing insights into its potential as a sustainable soil amendment agent. As a whole, the study evaluated a savings of around 46% irrigation water for the amended plots while compared to unamended one thereby proving the biochar efficiency to hold plant available water during water scarce conditions thereby presenting a valuable insight into the potential of rubber wood biochar for soil amendment.

Keywords: IoT Controlled Plot; Okra Growth; Rubber Wood Biochar; Water Holding Capacity

GRAPHICAL ABSTRACT (GA)



Insights into Biomass Pyrolysis: Particle Devolatilization and Structural Behavior via X-Ray Imaging and High-Pressure TGA

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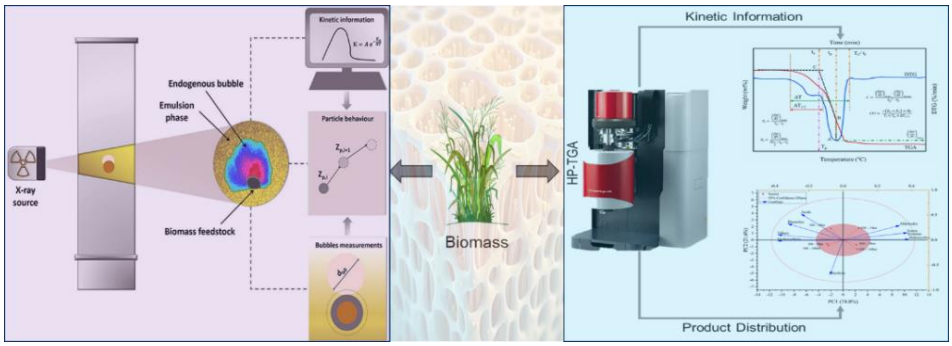
ABSTRACT

The intrinsic behavior of biomass pyrolysis in fluidized bed reactors is critical for optimizing conversion efficiency and product yield. By understanding particle dynamics and devolatilization mechanisms, we can enhance reactor design and operational parameters, facilitating effective scale-up for sustainable biofuel and chemical production. This study explores biomass pyrolysis, focusing on particle devolatilization and structural behavior using advanced X-ray imaging and high-pressure thermogravimetric analysis (HP-TGA). Biomass pyrolysis is essential for converting organic materials into sustainable biofuels and chemicals. Despite its potential, the complexities of biomass decomposition and the impact of operational parameters remain poorly understood. We utilized non-invasive X-ray imaging to analyze biomass particle behavior in a lab-scale fluidized bed reactor, providing insights into mixing and conversion mechanisms essential for optimizing reactor design. Understanding the kinetics of biomass decomposition is vital for advancing thermochemical conversion technologies as well. High-pressure thermogravimetric analyses were performed on biomass samples at temperatures ranging from 30 to 900 °C and pressures of 5, 10, and 20 bar, using advanced non-linear isoconversional methods to estimate kinetic parameters and assess the impact of pressure on product yield. The findings reveal important correlations between particle structure, devolatilization dynamics, and the effects of pressure, offering a more comprehensive understanding of biomass pyrolysis. By elucidating these mechanisms, this research contributes to the development of more efficient thermochemical conversion technologies, facilitating the use of lignocellulosic biomass and waste materials in producing sustainable fuels and chemicals. Ultimately, these insights pave the way for enhanced design and operation of biomass pyrolysis systems in real-world applications.

GRAPHICAL ABSTRACT (GA)



Exergy, CO_2 Emission, and Techno-Economic Analysis of DME Production via EFB Biomass Gasification

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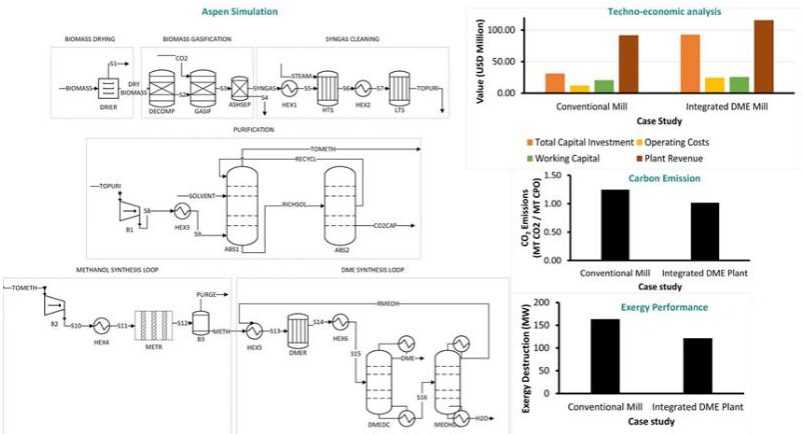
ABSTRACT

The relentless consumption of fossil fuels has caused significant environmental damage, particularly through carbon emissions. Addressing this critical issue requires an immediate shift toward sustainable energy sources, with a strong focus on biomass utilization. This study proposes transforming conventional palm oil mills into integrated facilities capable of co-producing palm oil and biofuels, specifically dimethyl ether (DME). By leveraging the gasification of Empty Fruit Bunch (EFB) biomass, which can be efficiently converted into syngas (a vital precursor for DME). While DME synthesis from various biomass sources has been widely researched, a significant gap exists in understanding the potential of DME production from EFB gasification, particularly exergy, carbon emissions, and techno-economic analysis. Using Aspen Plus software, this research simulates carbon emission analysis and a thorough techno-economic assessment of the integrated DME production via the EFB gasification route. Two distinct case studies were explored: i) the conventional palm oil mill (base case) and ii) the integrated DME plant. The findings reveal that the integrated process significantly outperformed conventional mills, with a 25% reduction in exergy destruction (lost work), a 33% increase in renewability index, and an 18% decrease in carbon emissions. Furthermore, the techno-economic assessment showed that the integrated complexes generated 26% more revenue than the conventional setup. These outcomes underscore the economic and environmental viability of integrating DME production through EFB gasification with palm oil mills, marking a critical shift from linear to circular economies to achieve zero waste emissions. This presents a transformative path toward sustainability and positions the palm oil industry at the forefront of biofuel innovation.

GRAPHICAL ABSTRACT (GA)



Pyrolysis of Algal Biomass for Sustainable Biochar Production: Investigating the Interplay of Processing Parameters and Material Properties

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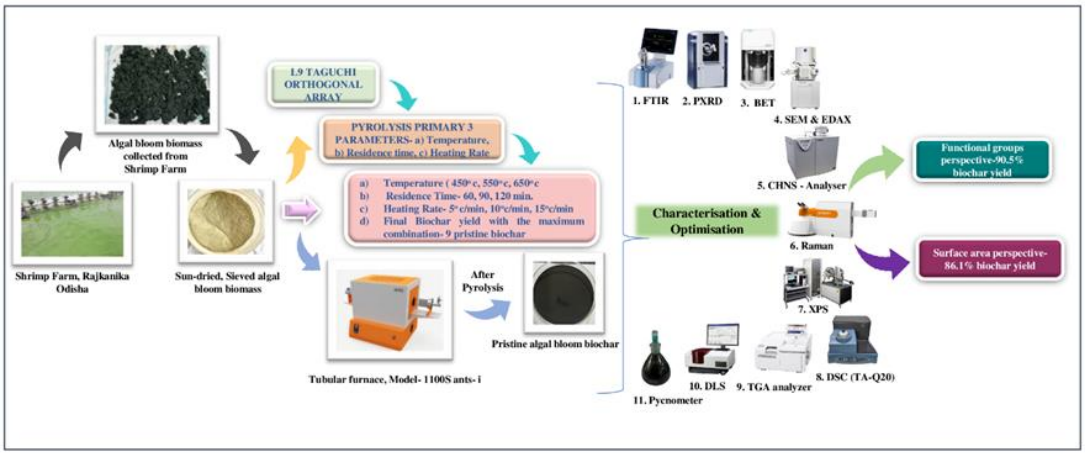
ABSTRACT

Algal blooms, a common environmental challenge in shrimp farming, offer a valuable opportunity for sustainable waste conversion into biochar. This study evaluates the feasibility of producing biochar from algal biomass through pyrolysis, focusing on optimizing three key process parameters: temperature, residence time, and heating rate. An L9 Taguchi orthogonal array was used to design the experiments. Biochar yield and quality were analyzed using advanced characterization techniques, including PXRD, FESEM, EDAX, CHNS, RAMAN, FTIR, BET, XPS, TGA, DSC analysis, particle density, and pH measurement, to understand the physicochemical properties of the resulting biochar. From the characterization data, the optimization of biochar yield in the context of functional groups perspective and surface area are 90.5% and 86.1%, respectively. The pyrolyzed product, pristine biochar, demonstrated that processing conditions significantly influence biochar structure and properties quantitatively and qualitatively. These findings provide insight into optimal pyrolysis parameters for enhancing biochar quality, with potential applications in environmental remediation and agricultural sustainability.

GRAPHICAL ABSTRACT (GA)



One-Pot Green Synthesis of Nio/Mgo Nano-Composite Catalyst for the Thermo-Catalytic Devolatilization Studies of Sawdust Pyrolysis and its Comparative Analysis with Industrial Zeolite and Dolomite Bulk Catalysts

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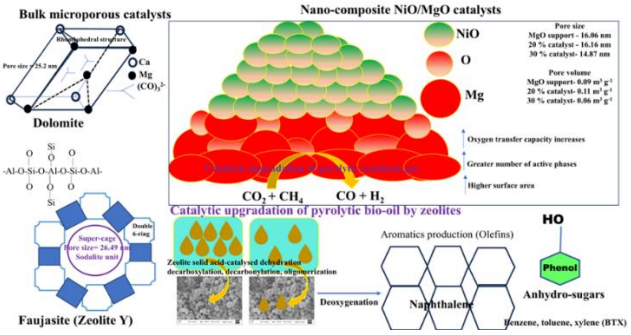
ABSTRACT

The study incorporates the effect of synthesized 20 % and 30 % NiO/MgO nano-catalysts, industrial zeolite and dolomite bulk catalysts on the catalytic co-processing of sawdust for its thermo-catalytic degradation studies. The physio-chemical composition of the industrial and synthesized catalysts by wetness impregnation technique are visualized for its elemental composition, morphological topology, crystal phase structure, presence of functional groups and surface binding energies, surface area analysis and studies on thermal stability characteristics. XRD analysis showed the presence of NiO_2-Mg and Bunsenite (NiO) for both 20 % and 30 % NiO/MgO, dolomite with chemical formulae of Ca-Mg-$(CO_3)_2$, inorganic mineral Zeolite Y with a chemical formula of $Na_{2.1}Mg_{21.7}(NH_4)_{13.5}Al_{59}Si_{133}O_{384}\cdot 240H_2O$. The crystallite size of MgO support, 20 % and 30 % NiO/MgO was 13.89 nm, 23 nm and 25.08 nm in comparison to zeolite and dolomite with 14.94 nm and 16.40 nm. Due to fewer surface catalytic sites of the smaller nanoparticles in 20 % Ni loaded catalyst, it substantiates the fact that 20 % Ni loaded catalyst has a greater number of active phases with higher surface area in the support increasing its catalytic activity. Surface area analysis showed BET surface area of 22.48 $m^2\ g^{-1}$, 27.24 $m^2\ g^{-1}$ and 17.90 $m^2\ g^{-1}$ for MgO support, 20 % and 30 % NiO/MgO catalysts in comparison to dolomite and zeolite catalysts with lesser BET surface area of 12.18 $m^2\ g^{-1}$ and 14.45 $m^2\ g^{-1}$. TG-DTG analysis indicated higher thermal stability of the catalysts at even lower temperatures. This visualized the thermo-catalytic devolatilization studies of sawdust pyrolysis at 5 %, 10 %, 15 % and 20 % of catalyst weight % in sawdust at process conditions of nitrogen as inert purge gas (19.8 mL min^{-1}), 20 K min^{-1} heating rate from 303-1173 K temperature and 1 bar pressure.

Keywords: Devolatilization; Dolomite; NiO/MgO nano-composite catalyst; Sawdust pyrolysis; Zeolite

GRAPHICAL ABSTRACT (GA)



Comparative Distribution and Characterization of Products from Fast Pyrolysis of Cooked Food Waste, Eucalyptus (Wood), and Bamboo (Non-Wood)

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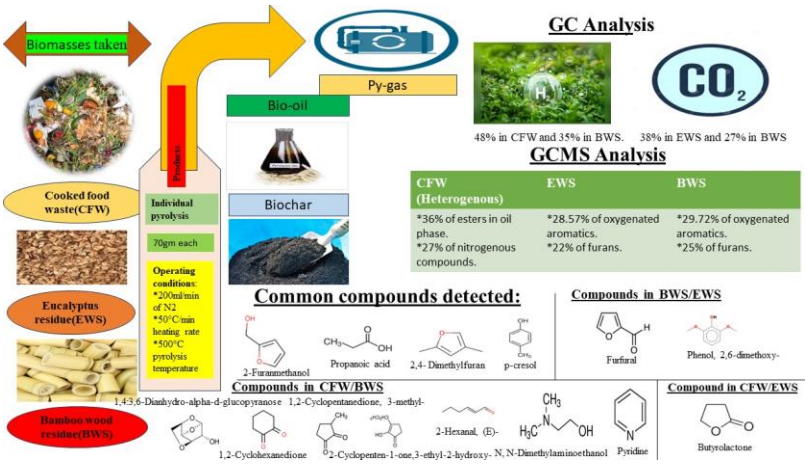
ABSTRACT

The present research work is the first attempt to compare products from fast pyrolysis of cooked food waste (CFW) with that from individual pyrolysis of woody biomass (eucalyptus wood sample (EWS)) and non-woody biomass (bamboo wood sample (BWS)). 70 grams of each of these dried samples was pyrolyzed with a final temperature of 500 °C at an optimum heating rate of 50 °C/min, where the sweep gas (nitrogen) flow rate was maintained at 200ml/min. The highest amount (30%) of bio-oil was obtained from bamboo wood, followed by eucalyptus (28%) and CFW (29%). Oil produced from CFW contained two phases, i.e., oil and aqueous, whereas the oil from EWS and BWS contained only one phase. The oil phase from CFW contained the highest fraction of FAMEs (36%), and the aqueous phase contained the highest fraction of nitrogenous compounds (29.35%). However, the bio-oil obtained from EWS and BWS has the highest fraction of phenolic compounds (28%) and furans (27.66%). Additionally, a comparative analysis is presented for each group of chemical compounds present in the bio-oil from CFW, EWS, and BWS. These groups of chemical compounds include nitrogenous compounds, esters, oxygenated aromatic compounds, carbonyl compounds, cyclic carbonyl compounds, furans, fatty acids, sugar-derived compounds, aliphatic compounds, and aromatic compounds. Furthermore, the highest fraction of biochar (32%) was obtained from eucalyptus wood, followed by 31% from bamboo and 30% from CFW. Furthermore, CFW showed the highest gas yield of 0.35 m^3/kg with 48% hydrogen in py-gas, whereas the EWS and BWS obtained the same gas yield (0.23 m^3/kg) with the highest fraction of carbon dioxide (38%) in EWS and highest fraction of hydrogen (35.21%) in BWS.

GRAPHICAL ABSTRACT (GA)



γ-Al_2O_3 Supported Bimetallic Catalyst with Controlled Metal Stoichiometric Ratios for Turquoise Hydrogen and Carbon Nanotubes Production

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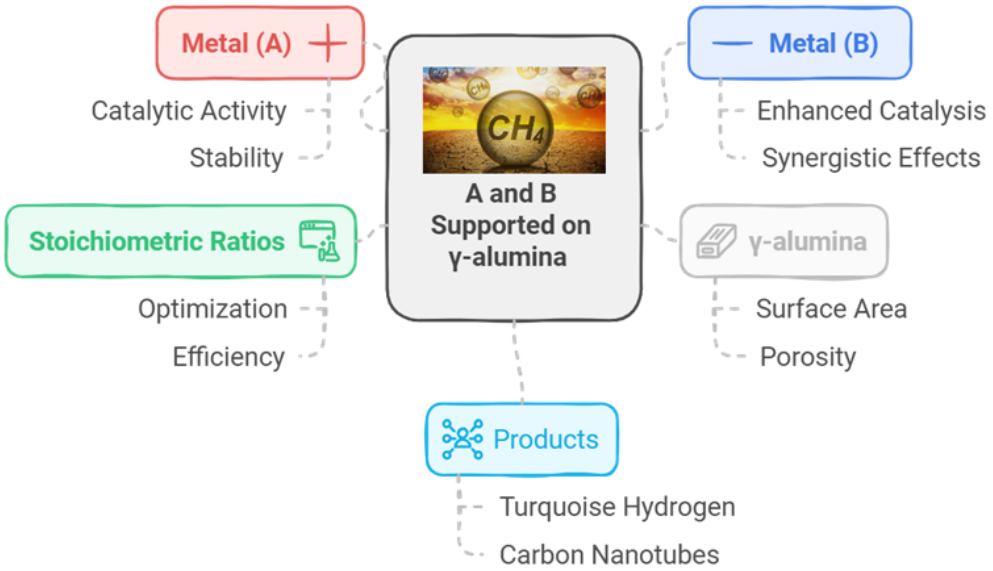
ABSTRACT

Synthesis of a bimetallic catalyst based on non-noble metals with a precisely controlled metal stoichiometric ratio is crucial for the effectiveness of any engineered material intended for use in methane cracking to produce hydrogen and solid carbon (C). Herein, we synthesized a series of bimetallic catalysts supported on γ-alumina nanopowder (A-B/γ-Al_2O_3) by tuning the stoichiometric ratio of the metals using a simple co-precipitation method. The metal A and B content ranged from 0 to 70 weight percent (wt%). The structural and morphological characteristics of the freshly prepared catalysts varied with changes in the A and B ratios. Synthesized catalysts showed robust performance in methane cracking at 750 °C, generating turquoise hydrogen and carbon nanotubes (CNTs). Our best catalyst (A3B4), with 30% A and 40% B, achieved a maximum methane conversion rate of 85% and a hydrogen yield of 72.5%. Moreover, the turnover frequency (2.38 min^{-1}) indicated that A3B4 had a higher production rate and maintained consistency throughout the reaction. The structural analysis of the spent catalysts showed differences in the lateral length, uniformity, and diameters (~33 to 56 nm) of the produced CNTs when transitioning the metal ratio from 0 to 70%. This study highlighted the importance of metal stoichiometrically controlled catalyst synthesis in boosting catalytic performance in methane cracking applications.

GRAPHICAL ABSTRACT (GA)



Development of A Quantitative Method for A Trace Amount of Microplastics by Pyrolysis GC/MS/MS

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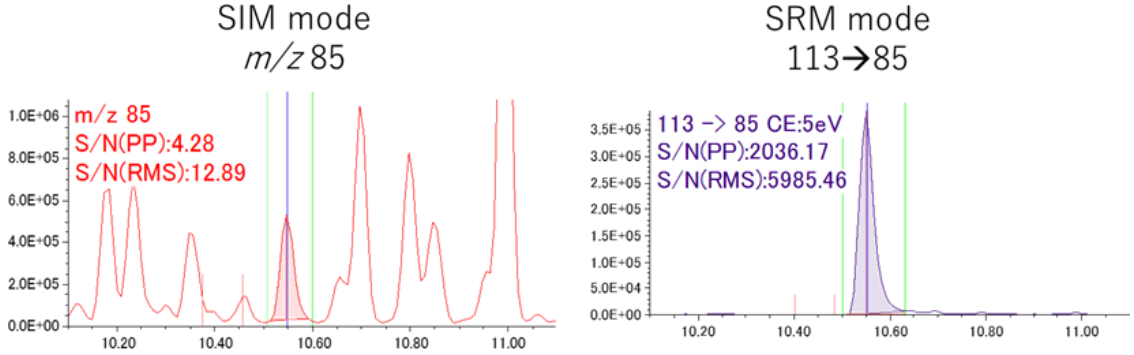
ABSTRACT

Microplastics (MPs) are plastics with particle sizes of 5 mm or less. In recent years, the development of analytical methods for tracing MPs has been considered important from the viewpoint of environmental impact and risk to the human body. Various techniques are used for MPs analysis, such as observing surface structure by electron microscope and confirming molecules and functional groups by FT-IR. On the other hand, as a measurement method for GC/MS, measurement by GC/MS combined with a pyrolysis device is employed. The polymer species that are the main components in a sample can be identified using GC-MS in Scan mode, but trace components must be monitored in selected ion monitoring (SIM) mode. However, SIM measurement is easily affected by impurity components from polymer components and additive components present in large amounts, making it challenging to confirm trace polymer components by SIM measurement. In contrast, selected reaction monitoring (SRM) measurement of GC/MS/MS is performed by measuring a combination of selected precursor ions and product ions. It can increase the selectivity of trace components and reduce the influence of impurity components. In this presentation, we report on method development for qualitative analysis of trace amounts of MPs using pyrolysis GC/MS/MS. Figure 1 shows the results of SIM (*m/z* 85) and SRM (*m/z* 113→85) measurements of polypropylene with 500 ng of polyamide 66 added. The selectivity of SRM was high compared to SIM, with an S/N ratio of 400 times or more.

GRAPHICAL ABSTRACT (GA)



	SIM mode (m/z 85)	SRM mode (113→85)
S/N(RMS) value	12.89	5985.46

HDPE Bottle Cap Waste Upgrading Through Two-Stage Catalytic Pyrolysis Using Tandem Microreactor-GCMS

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ABSTRACT

High-density polyethylene (HDPE) is used in a diverse range of applications, including plastic bags, containers, piping, plastic bottles, and bottle caps. The majority of products made by HDPE are single-use plastics and this directly causes plastic waste and environmental pollution. Pyrolysis is a technique that aids in converting waste into valuable chemicals. The bottle cap waste was collected from bottles of water with the resin identification Code 2 (HDPE). It was cleaned, cut by rotor mill and cryogenic mill, respectively. The obtained HDPE waste powder analyzed by thermogravimetric analysis (TGA) for decomposition behavior. Subsequently, it was pyrolyzed without catalyst at 400-600 °C in Tandem Microreactor-GCMS. Long chain aliphatic hydrocarbons (C_{12}-C_{23}) were produced from thermal pyrolysis as main products. The HDPE waste catalytic pyrolysis was studied in an in-situ system using Al-SBA-15 and zeolite HY as catalysts. The Al-SBA-15 provided higher gasoline range (C_6-C_{11}) hydrocarbons from 19.8% to 30.8% compared to thermal pyrolysis at 500 °C. Whereas HDPE waste catalytic pyrolysis over microporous zeolite HY improved bio-oil product obtaining benzene (B), toluene (T), ethylbenzene (E), and xylene (X). The BTEX compounds were produced up to 12.2% at 600 °C. In the meantime, C_3, C_4 and C_5 hydrocarbons were increasing to 7.0%, 25.5%, and 24.6%, respectively. Both catalysts showed promising results in upgrading HDPE waste into high-value chemicals. Therefore, two-stage catalytic pyrolysis of HDPE waste using both catalysts is interesting. The HDPE waste and Al-SBA-15 were added into the 1st microreactor while the zeolite HY was separately packed into the 2nd microreactor. The BTEX compounds were rising to 17.6% in two-stage system at 500 °C of 1st microreactor and 600 °C of 2nd microreactor. Moreover, the HDPE waste to catalyst ratio will be evaluated in two-stage catalytic pyrolysis.

GRAPHICAL ABSTRACT (GA)

Catalytic Cracking of Plastic Waste Fractions: Kinetic and Thermodynamic Parameter Estimation Through Non-Linear Approach

Kartik S[1], Hemant Balsora[1], Alok Gautam[1], Chiranjeevi Thota[2], Anand G Chakinala[4]
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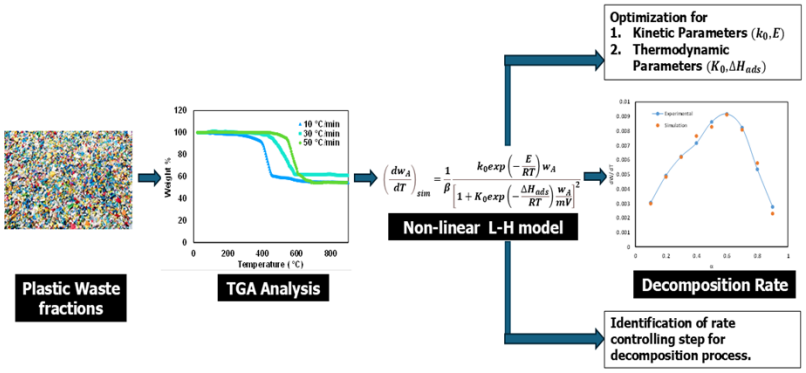
ABSTRACT

Performance of cracking reactions for energy extraction and production of value-added components from plastics largely depend on understanding decomposition kinetics. Degradation of plastic fractions Low/High Density Polyethylene (LDPE, HDPE) and Polypropylene (PP) through catalytic cracking has been explored in present study with spent FCC catalyst. A non-linear Langmuir Hinshelwood model developed predicts rate of catalytic decomposition in temperature range of 30–900 °C. Rate estimations closely match experimentally evaluated values at heating rates of 10, 30 and 50 °C/min. The activation energy values for LDPE & HDPE is about 155 kJ/mol, which is 38% less when compared with similar values for thermal cracking. For PP, energy of activation is 140 kJ/mol representing a drop of 32% as compared to thermal cracking. Higher activation energy values obtained for LDPE and PP as compared to heat of adsorption specify the rate controlling step as degradation of substrate on active site of catalyst rather than adsorption phenomena. In case of HDPE, the catalytic decomposition is controlled by adsorption of substrate on catalyst due to its compactly packed structure of HDPE having lesser extent of branching. Overall, this research provides valuable insights into the kinetics of plastic fraction cracking and highlighting the potential of catalytic processes in reducing energy requirements.

GRAPHICAL ABSTRACT (GA)



Removal of Emerging Pollutants (*Ciprofloxacin antibiotics*) from Wastewater Using Waste Biomass: A Kinetics, Isotherms, and Thermodynamics Study

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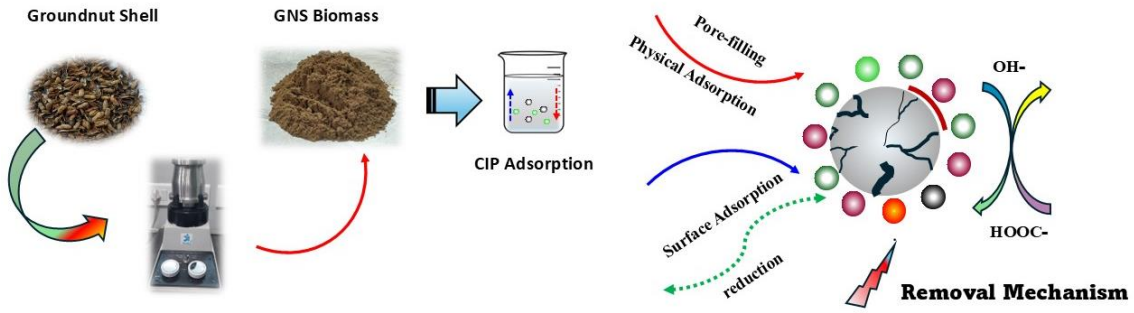
ABSTRACT

Antimicrobial resistance is one of the challenging global issues owing to rapid utilization and unprescribed use of antibiotics. Moreover, developing countries are more affected due to various social aspects such as lack of awareness for overdosing, early medication, and over-the-counter sale of antibiotics. There are many types of antibiotics, Ciprofloxacin being one of them, which is used for treating a number of bacterial infections. In the present work, ground nutshell (GNS) biomass derived from agricultural waste was used for the adsorption study of ciprofloxacin antibiotic. The GNS biochar was prepared using a mechanical blending process followed by drying. The prepared biomass has been used for the adsorption of ciprofloxacin (CIP). Different experimental parameters were studied, including solution pH, agitation time, adsorbent dose, initial concentration of adsorbate, and temperature. Four isotherm models (viz. Freundlich, Langmuir, Dubinin-Radushkevitch (DR), and Temkin isotherms model) have been studied for the removal of CIP on the GNS surface. Batch experimental finding suggested that the adsorption of CIP follows the Langmuir and Temkin models (with R^2 values of 0.985 and 0.981 respectively). The maximum adsorption capacity of CIP was evaluated as 4.99 mg/g with a 61.4 % removal of CIP in initial 50 min. The kinetic study reveals that adsorption follows the pseudo-second-order linear kinetics model with R^2 values of 0.998. Thermodynamic study indicates that the reaction is endothermic and proceeds spontaneously for the sorption of CIP. This study shows the potential of waste biomass for removing emerging pollutants and provides insights towards achieving the sustainable development goals.

Key Words: Agricultural Waste; Antimicrobial Resistance; Ciprofloxacin; Groundnut shell; Adsorption Isotherm; Kinetics

GRAPHICAL ABSTRACT (GA)



Artificial Neural Network Based Models for the Prediction of Pyrolysis Product Distribution Using Preliminary Analysis

Hemant Kumar Balsora[1*], Kartik S[1], Anand G Chakinala[2], Jyeshtharaj B Joshi[3], Abhishek Sharma[2,4]

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[2]Waste to Resources Laboratory, Department of Biotechnology and Chemical Engineering, Manipal University Jaipur, Rajasthan, 303007 India.
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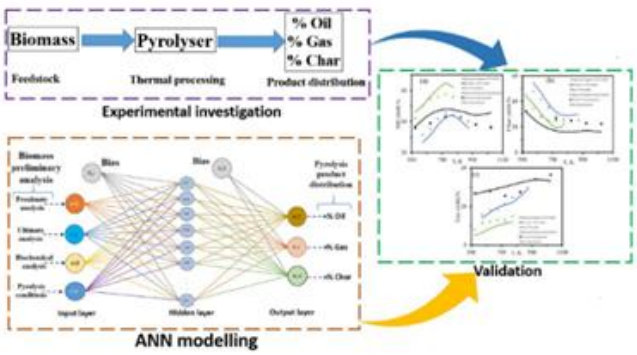
ABSTRACT

Lignocellulosic biomass is a complex feedstock for pyrolysis, and the products produced during pyrolysis vary with respect to feedstock and operating conditions. In this study, machine learning methods were used to predict the yield of pyrolytic fractions using data sets of pyrolytic product distributions, operating conditions, and feedstock characterization from a diverse range of biomass. This work aims to develop ANN models and investigate the effects of these factors on pyrolysis product distribution. Seven artificial neural network (ANN) models were developed by utilizing different types of analyses. These models include proximate analysis-based (ANN-P), ultimate analysis-based (ANN-U), and biochemical analysis-based (ANN-B), combined proximate-ultimate analysis-based (ANN-PU), combined ultimate-biochemical analysis-based (ANN-UB), combined proximate-biochemical analysis-based (ANN-PB), and combined proximate-ultimate-biochemical analysis-based (ANN-PUB) models. A total of 1,134 datasets were extracted from previously published literature and sequentially, 947, 973, 585, 897, 558, 514, and 495 datasets were used to develop these models. The developed models showed competitive prediction capability. In particular, the models ANN-PB, UB had a prediction capability with R^2 ~ 0.96, RRMSE <7.5%, and MAE < 0.06, and ANN-PUB had a prediction capability with R^2 ~ 0.97, RRMSE < 5.60%, and MAE ~ 0.04. The relative importance of each input on outputs (product yields) showed that biomass polymers Cell and Lig affect the product distribution highest to an extent of ~8.8 and ~7.8%, respectively.Through this investigation, valuable insights can be gained, contributing to the optimization and enhancement of biomass pyrolysis processes for biofuel production.

GRAPHICAL ABSTRACT (GA)



In-situ Transmission Electron Microscopy for Understanding Pyrolysis of Polymers for Device Fabrication

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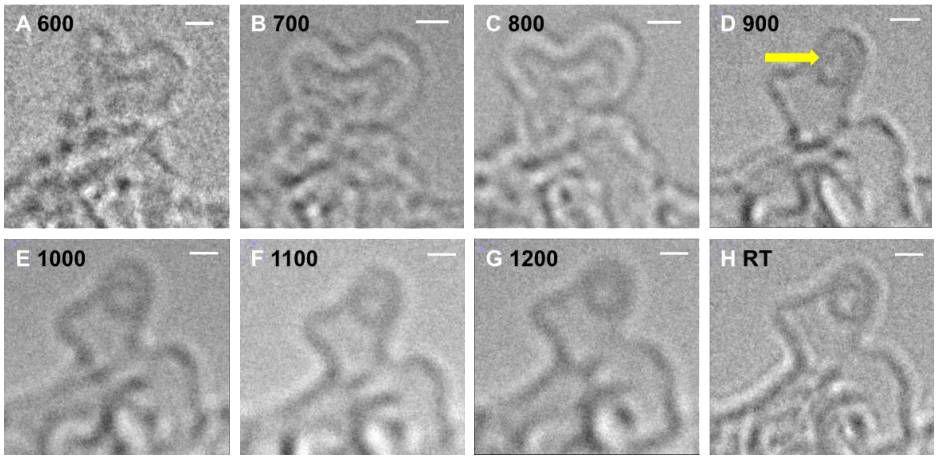
ABSTRACT

Pyrolysis of solid organic materials has versatile applications ranging from waste-treatment to micro- and nano carbon device fabrication. While large-scale waste pyrolysis involves a number of unknowns including the exact composition of the organic material, in the case of device fabrication often a known polymer is patterned and heat-treated. This heat treatment ultimately yields a carbon material above 900^{o} C. This process, the evolution of a carbon material from polymers, has been studied at molecular level utilizing a number of analysis techniques. In our group, we carry out in-situ TEM studies where a polymer film is heated on to a Joule-heated chip inside a microscope and its microstructure is simultaneously imaged. A series of images recorded at increasing pyrolysis temperatures is shown in the graphical abstract. This study has been used for understanding the microstructure of a carbon material derived from a phenolic resin. While this is a very promising technique for analysis of a pyrolyzing polymer, it also comes with a number of challenges. In this talk, various aspects, pros and cons, and required instrumentation for in-situ TEM of pyrolysis will be discussed.

GRAPHICAL ABSTRACT (GA)



(A-H) A series of high-resolution TEM images of a pyrolyzing phenolic resin. Heat-treatment temperature in ^{o}C is shown in the top left corner. All scale bars are 1 nm.

Rapid Analysis of Pyrolysis Oil Using Blank Tube-FI Method and GC-EI/FI Method

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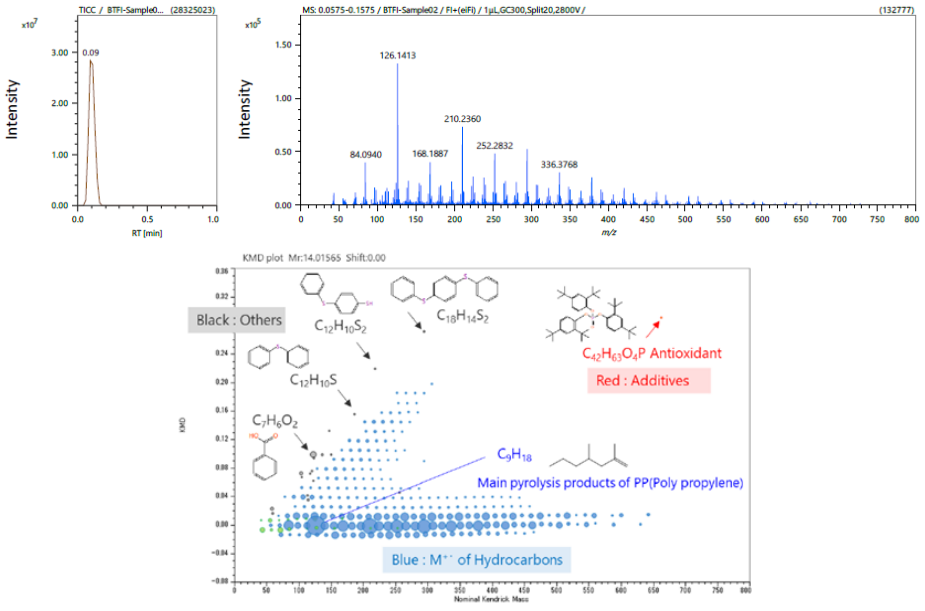
ABSTRACT

In the blank tube-FI (Field Ionization) method, a sample is introduced into the GC injection port, passed through a blank tube, and then detected using the soft ionization FI method. It is possible to detect molecular ions in less than one minute. When measuring a mixture of hydrocarbons such as oil, a complex mass spectrum containing multiple molecular ion peaks is obtained. Even in this case, qualitative information can be easily obtained by KMD (Kendrick Mass Defect) analysis. By using GC-EI/FI method in combination, it is possible to obtain structural formulas that cannot be obtained by the blank tube-FI method alone. In this study, we will introduce the analysis results of pyrolysis oil using these methods. The TICC and mass spectrum obtained using the blanktube-FI method are shown below.

The KMD plot created from the above mass spectrum is shown below. Ion peaks derivedfrom compounds with a common repeating structure are arranged in a straight line, making it possible to visually separate the components. Furthermore, each ion peak has accurate mass information, so it is possible to estimate the composition formula. By combining with the structural formula obtained by the GC-EI/FI method, it is possible toefficiently evaluate the sample. In this result, in addition to the main component hydrocarbons, sulfur compounds and antioxidants that affect oil quality were identified.

GRAPHICAL ABSTRACT (GA)



Reimagining Aroma Extraction Waste: Catalytic Pyrolysis forHydrocarbon Production

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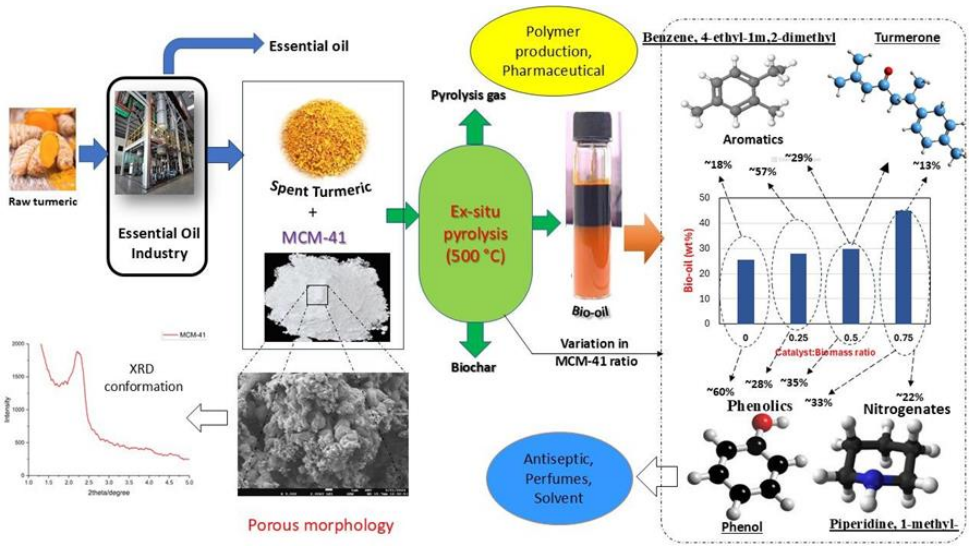
ABSTRACT

The utilization of organic and organically produced items has grown more prevalent in modern human culture. This rising demand for natural and clean-label goods is propelling substantial growth in the market for isolated aromas, essential oils, and fats. The food and beverage industry predominantly depends on oleoresins and aroma extracts. Consequently, the aroma extraction process generates substantial amounts of solid waste, containing relatively low concentrations of oil and oleoresins (10-20%). This research examines the potential value- added applications of solid waste from the aroma extraction industry, specifically spent turmeric (ST), through a thermochemical conversion method known as catalytic pyrolysis. TheST was subjected to pyrolysis at 500°C with a heating rate of 10°C/min in a nitrogen atmosphere with a flow rate of 200 ml/min and varying catalyst-to-biomass (C/B) ratios. The yield of bio-oil increased to 40 wt% at a C/B ratio of 0.75, indicating that the catalyst effectivelymitigates secondary cracking of condensable vapors. The GC-MS analysis of the bio-oil identified phenolics as the predominant compounds (65%), including cresol and phenol, with a secondary presence of aromatics (18%), such as benzene. The introduction of MCM-41 at a ratio of 0.25:1 resulted in a reduction of phenolics to 28% and an increase in aromatics to 57%.Further increases in the MCM-41 ratio to 0.5:1 and 0.75:1 led to decreased levels of phenolicsand an emergence of sesquiterpenoids and nitrogenous compounds, alongside increased aromatic content.

GRAPHICAL ABSTRACT (GA)



Optimizing Biomethane Potential and Biochar Production via Co-Digestion and Pyrolysis/Gasification of Food and Garden Organics with Activated Sludge

Nimesha Rathnayake[1,2], Sudhakar Pabba[1,2], Leadin Khudur[1,2], Ibrahim Hakeem[1,2], Kalpit Shah[1,2]

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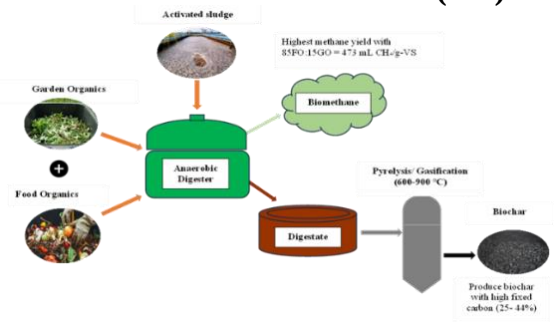
ABSTRACT

This study explores the feasibility of integrating anaerobic digestion (AD) with thermal processes (pyrolysis/gasification) for efficient energy recovery and biochar production from food and garden organics (FOGO) and sewage sludge. The research aims to evaluate biomethane potential (BMP) of FOGO through co-digestion with secondary sludge. In addition, biochar yield, properties, and contaminant reduction obtained from the pyrolysis and gasification of the digestate was studied. Different combinations of FOGO with activated sludge were tested using a 21-day mesophilic AD process. The study assessed three feedstock ratios based on monthly FOGO collection data, focusing on food organics as the limiting feedstock. The findings showed that increasing the proportion of food organics in the feed mix to the AD significantly improved biomethane yields, with the highest yield of 473 mL CH_4/g-VS achieved at an 85FO:15GO ratio. Following AD, the resulting digestates were subjected to pyrolysis/gasification at 600-900°C, producing biochar with high fixed carbon content of 25-44 w%. Furthermore, results revealed that higher temperatures improved the fixed carbon content while reducing volatile matter in the derived biochar. For instance, pyrolysis of the digestate from 54FO:46GO at 600 °C yielded biochar with a fixed carbon content of 44%, compared to 40% fixed carbon from pyrolysis at 700 °C. Furthermore, gasification at 600 °C produced biochar with significantly lower fixed carbon (25%) than pyrolysis (34%). Both thermal treatment processes significantly reduced contaminants, with PFAS concentrations below detection limits and PAH concentrations consistently below 0.2 mg/kg in the produced biochar. The most substantial contaminant reductions were observed at 900 °C for gasification and 700 °C for pyrolysis. Overall, this integrated approach highlights the potential of co-digesting FOGO waste with activated sludge, followed by pyrolysis and gasification of the digestate, to optimize biomethane and biochar production while managing contaminants inherent in the feed streams.

GRAPHICAL ABSTRACT (GA)



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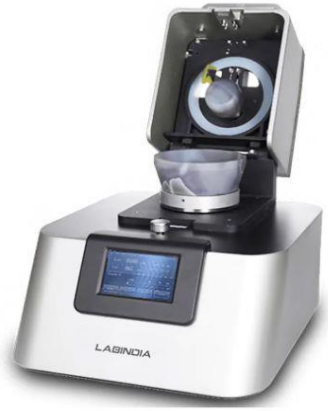

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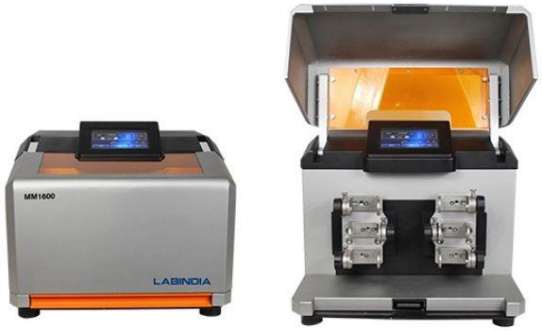

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Poster Presentations

Fabrication of Biofilms using Plant-Based Extract for the Food Packaging Application: A review

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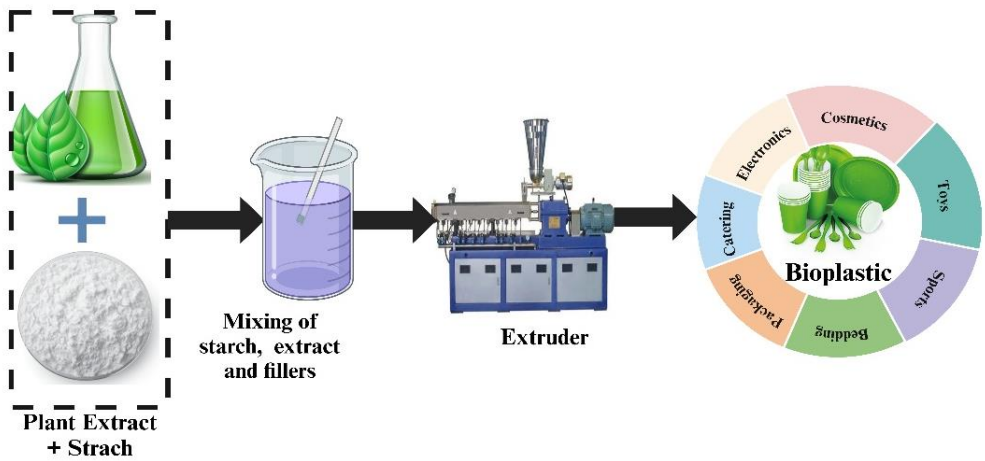
ABSTRACT

The food packaging sector is one of the top users of plastic, leading to environmental concerns and the depletion of fossil fuel resources. It comprises around 39.50% of total plastic production leading to the search for sustainable alternatives to conventional plastics. Natural extracts, such as plant-derived oils and polysaccharides, provide biodegradable and eco-friendly components, while starch offers an abundant and renewable polymer base. The present review highlighted the synthesis and characterization of bioplastics fabricated using plant-based extract for food packaging applications. Further, this paper discussed in-depth information about the synthesis of bioplastics such as solvent casting, extrusion, tape casting, thermoforming, injection molding, etc. Also, it covers the different types of extruders (single, twins, reactive, blown, and co-extrusion) for the synthesis of bioplastics. Various synthesis techniques such as blending, grafting, and chemical modification are examined to enhance the compatibility and performance of the bioplastic composites. The characterization of biofilm such as Fourier Transform Infrared Spectroscopy, Scanning Electron Microscopy, Thermogravimetric analysis etc., was also studied and discussed in-depth. Further, Thermal properties, mechanical properties, chemical properties, biochemical properties, and physical properties were addressed whereas, the barrier properties of biofilms were studied to support the use of bioplastic in food packaging applications.

Keywords: Bioplastics; Food packaging; Plant extract; Starch; Synthesis

GRAPHICAL ABSTRACT (GA)



Pyrolysis Behaviours and Kinetic Study of Non-Edible Waste Castor Seeds into Renewable Liquid Fuel and Value-Added Chemicals

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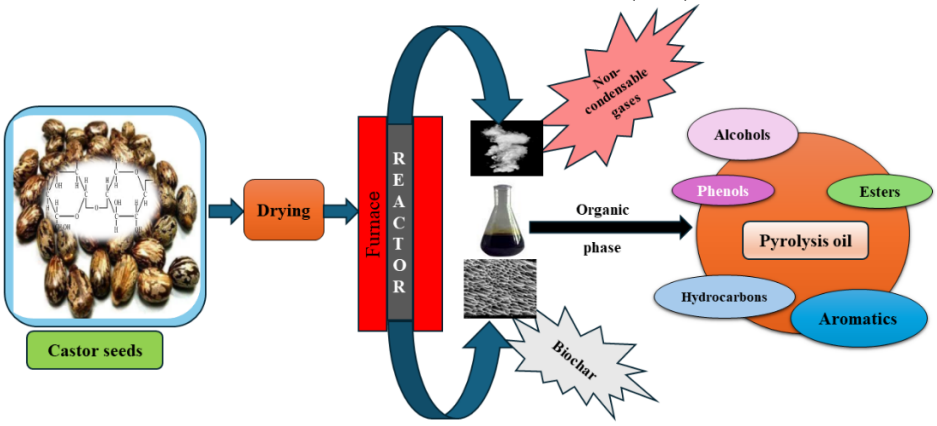
ABSTRACT

A thorough understanding of the characteristics of biomass pyrolysis offers essential insights for the design of pyrolysis equipment and process optimization. The present study focused on the thermal decomposition profiles, kinetics analysis, bio-oil and biochar production. The kinetic analysis of castor seeds (CS) was performed using the Friedman (FM), Ozawa-Flynn-Wall (OFW), Starink (STM), Kissinger-Akahira-Sunose (KAS), and Criado model. However, the bio-oil and biochar were produced in a semi-batch reactor at 450, 500 and 550 °C, 10 °C.min^{-1} heating rate, and 100 mL inert gas flow rate. The average apparent activation energy of CS from KAS, OFW, ST, and FM was found to be 172.75, 174.21, 173.03, and 156.47 kJ.mol^{-1}, respectively. The thermal decomposition profile of CS was confirmed by increasing heating rates from 10-50 °C min^{-1}, and TGA curves shifted towards a higher temperature zone. Further, pyrolysis text confirmed 48±0.95 bio-oil, 15±0.74 biochar and 37±0.68 syngas, respectively, at 500 °C. The characterization of bio-oil confirmed improved properties of bio-oil (reduced oxygen content, increased carbon content and higher heating value) at 500 °C than at 450 and 550 °C. Further, the characterization of biochar confirmed 55% carbon, 1.6% hydrogen, 16.12 MJ.kg^{-1} heating value, and 585 kg.m^{-3} bulk density. Also, FTIR and SEM analysis of biochar (CSB) confirmed that CSB is rich in aromatic compounds and has a very rough surface structure.

Keywords: Biochar; Bio-oil; Castor seeds; Kinetic parameters; Pyrolysis

GRAPHICAL ABSTRACT (GA)



Temperature-Dependent Pyrolysis of Biomass Feedstocks: Chemical Characterization of Bio-Volatiles from Cashew Nuts and Pine Needles

Sowkhya Naidu[1], Sivasankar Kakku[1], Jyeshtharaj Joshi[2], Abhishek Sharma[1,3*]

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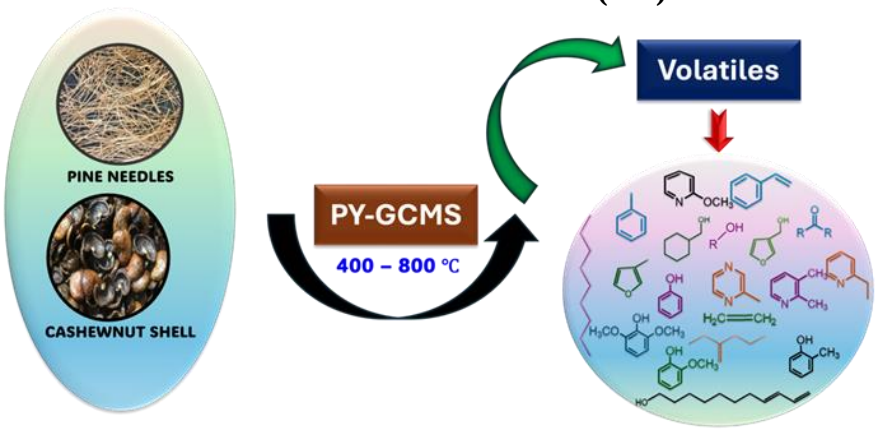
ABSTRACT

Bioenergy is gaining significant attention due to the increasing global demand for renewable and sustainable energy sources. Among various biomass feedstocks, cashew nuts and pine needles are abundant but require efficient waste-management solutions such as pyrolysis. This study aims to compare the chemical composition of bio-volatiles derived from these two feedstocks using Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GCMS) while varying pyrolysis temperatures between 400 and 800 °C. The results indicate that, as the temperature increases, the production of volatiles increases, while the solid residue decreases. The primary bio-volatile compounds identified in cashew nuts include phenolics, ketones, acids, alcohols, and aromatics, with phenolics being the dominant. Pine needles also contain phenolics, ketones, aromatics, alcohols, and acids, with phenolics as the predominant compound. Notably, cashew nuts exhibit increased phenolic content with temperature, whereas pine needles show an initial increase followed by a decrease as temperatures rise. Both feedstocks had an optimal temperature of 500 °C, where phenolics were most abundant. Thermal degradation was observed from the thermogravimetric analysis (TGA), and additionally, FTIR, proximate, and ultimate analyses were also carried out to understand the biomass characterization. This comprehensive study provides insights into optimizing pyrolysis conditions for efficiently converting biomass waste into valuable bio-oil products.

GRAPHICAL ABSTRACT (GA)



Optimizing Pine Needle Pyrolysis: Role of Chemical and Thermal Pre-Treatment

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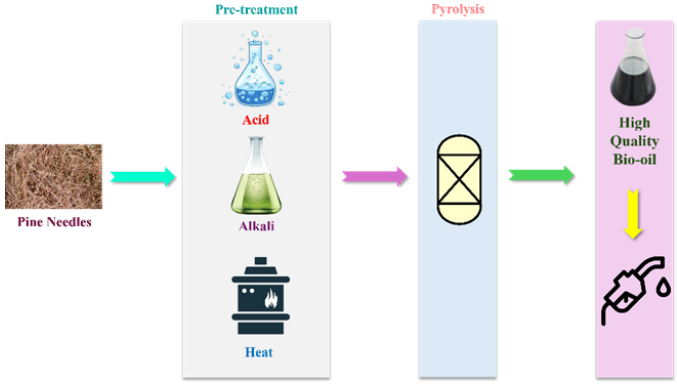
ABSTRACT

The current study investigates the impact of chemical and thermal pre-treatments on the pyrolysis behavior of pine needles, a forestry residue abundant in the Himalayan forests of northern India. Pre-treated biomass samples underwent several characterization techniques to assess the effects of these treatments. Proximate analysis revealed a significant reduction in moisture and ash contents after pre-treatment, alongside an increase in fixed carbon content. CHNS analysis showed that torrefaction and acid treatments notably reduced oxygen content as compared to the raw sample, while alkali treatment led to an increase in oxygen levels. XRF analysis further confirmed that acid treatment was highly effective in removing alkali and alkaline earth metals (a reduction of ~ 83%) present in raw feedstock (45.9%), whereas the alkali-treated (60.8%) and torrefied (53.8%) samples showed increased metal content. In terms of mass loss, the alkali-treated sample exhibited the highest loss, primarily due to lignin degradation, while the torrefied sample showed the least mass loss. Among the pre-treated samples, the torrefied biomass had the highest heating value (19 MJ/kg) and energy density, while the alkali-treated sample had the lowest in both aspects. Pyrolysis of the pre-treated and raw pine needles demonstrated substantial changes in bio-oil yield and quality. Under optimum reaction conditions (450 °C and 10 °C/min), acid treatment improved the bio-oil yield (46.5%) compared to the raw sample (41%), whereas both alkali (30%) and torrefaction (35.5%) treatments reduced the yield. The heating value of the bio-oil was highest for the torrefied sample (24.22 MJ/kg), while the alkali-treated sample showed the lowest. Additionally, the water content was lowest in the torrefied sample and highest in the alkali-treated sample. These findings highlight the varying effects of different pre-treatments on the pyrolysis characteristics of pine needles, and emphasize the potential of torrefaction for improving bio-oil quality and biomass energy density.

GRAPHICAL ABSTRACT (GA)



Kinetic and Thermodynamic Analysis of Pyrolysis of Microalgal Biomass: Using Model Free Approaches

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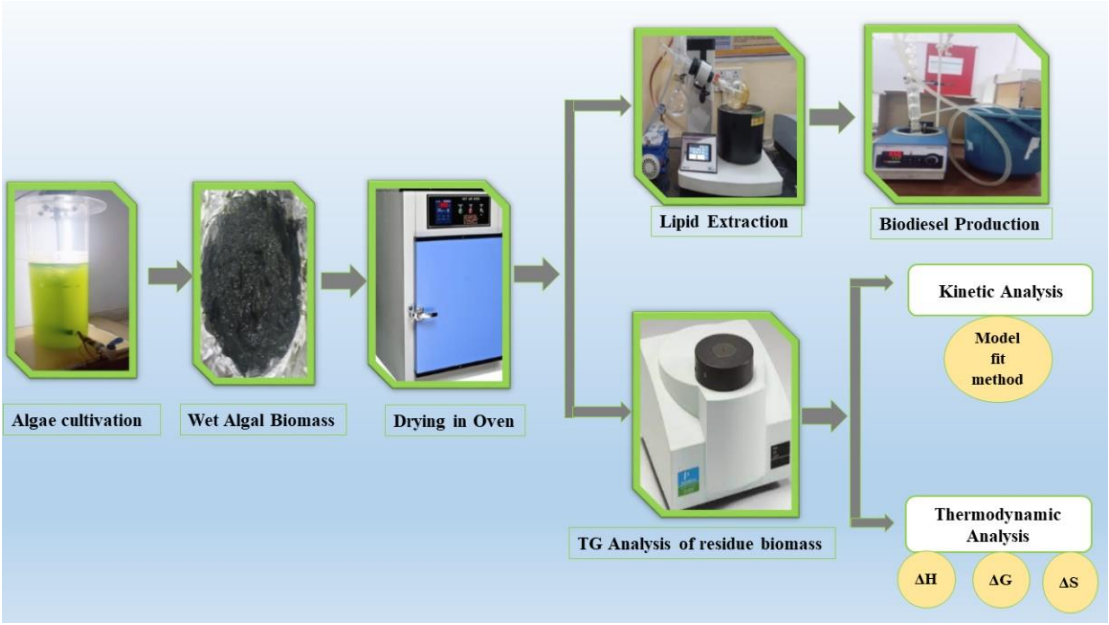
ABSTRACT

Lately, algae and their biomass residues are attracting growing interest for energy recovery. Pyrolysis, an essential thermochemical process, is gaining prominence as a viable "waste-to-energy" solution, offering versatility in producing a variety of products with precise selectivity, tailored to meet the specific needs of end users. This study explores the complete utilization of algal biomass through sequential chemical (transesterification) and thermochemical (pyrolysis) processes. Initially, the lipids were extracted and converted to eco-friendly biodiesel using catalytic route. Then lipid-extracted microalgae were pyrolyzed via thermogravimetric analyzer at four heating rates, namely 5, 10, 20 and 30 °C/min. The model-free isoconversional Kissinger-Akahira-Sunose (KAS), Flynn-Wall-Ozawa (FWO), Starnik, and Vyazovkin models were used to analyze the kinetics and thermodynamics of algal pyrolysis. The activation energy (E_a) obtained for the pyrolysis of *Chlorella minutissima* utilizing KAS, FWO, Starnik and Vyazovkin were estimated as 146.78, 148.86,147.12, 147.13 kJ/mol, respectively. Positive ΔH values from KAS, FWO, and Vyazovkin show an endothermic nature of the process. The mean ΔH was found to be 142.81, 151.90, 142.31, and 142.82 kJ/mol, respectively for KAS, FWO, Starnik, and Vyazovkin approaches, at 10 ºC/min heating rate.

GRAPHICAL ABSTRACT (GA)



Characterization and Nutrient Availability of Biochar Produced from Slow Pyrolysis of Commercially Cultivated Spirulina

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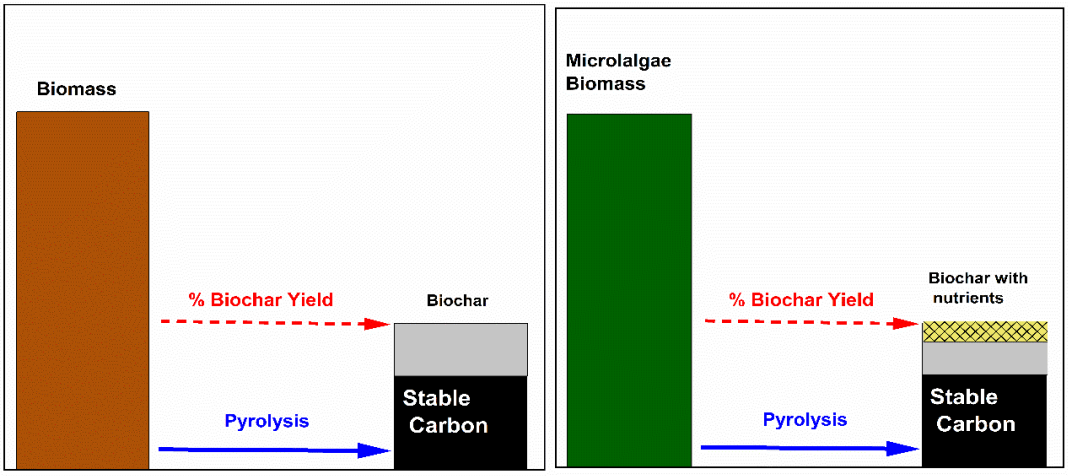
ABSTRACT

Biochar production from different biomass has received great attention in addressing some important environmental issues, especially concerning carbon sequestration and improving soil quality. Biomass with major plant nutrients like Nitrogen (N) and phosphorus (P) can produce nutrient-rich biochar that can be an important source of secondary fertilizers. In this study, *Arthrospira platensis* (commonly known as spirulina because of its spiral shape), which is phylogenetically a cyanobacteria but is referred to as microalgae due to its historical classification as blue-green algae was used for biochar production by slow pyrolysis. The algal biomass was subjected to various temperatures (such as 400,450,500, 550 °C) with a retention time of 60 minutes and a heating rate of 5°C/min. Proximate and ultimate analyses were done to understand the changes in biochar characteristics at various temperatures. The biochar yield reduced from 44.64 % at 400 °C to 28.71% at 550 °C. Thermogravimetric Analysis (TGA) and Differential gravimetric analysis (DTG) were further done to understand thermal degradation behaviour. The biochars produced were further analysed with SEM-EDS, XRD, and FTIR to examine the temperature changes. The total nitrogen (TN by elemental analysis), total phosphorous (TP by modified dry ashing), available nitrogen (2M KCl) and available Phosphorous (2%FA, 2% CA, Neutral ammonia citrate) in the biochar produced were quantified. However, this suggested that though the produced biochar is rich in nutrients (N and P) but is not bioavailable implying further modification is necessary to be used as a source of secondary fertilizers for N and P.

GRAPHICAL ABSTRACT (GA)



Impact of Agricultural Waste-Derived Biochar on Rice Seed (*Oryza sativa*) Germination and Growth: A Study of Varying Concentrations

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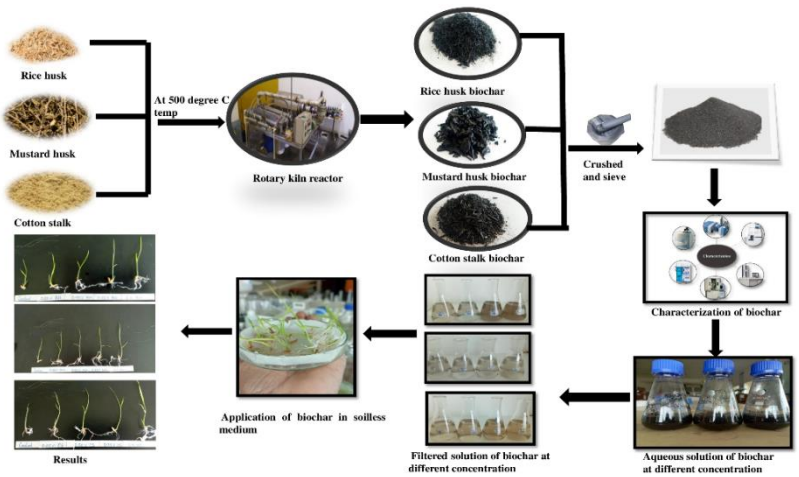
ABSTRACT

Biochar derived from agricultural waste is becoming increasingly popular for its ability to boost plant growth, improve soil qualities, and contribute to sustainable agriculture. This study investigates the impact of various biochar types and concentrations on the germination and early development of rice *(Oryza sativa*) seedlings grown in a soil-less medium. Biochar was produced from rice husks, Mustard husks and Cotton stalks by pyrolysis and characterized using techniques such as scanning electron microscopy (SEM), X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) to determine the surface morphology, crystalline structure and functional groups. The biochar was then applied to Petri plates in soilless media at concentrations ranging from 0.5% to 1% Germination rate, seedling vigour, and root and shoot length were assessed for all treatments and a control group without biochar. Biochar application significantly enhanced rice seed germination and growth, with optimal results at 0.5% to 1% biochar concentrations. Moreover, the type of biochar used also influenced the response, with cotton stalk biochar exhibiting the most pronounced positive effects. Excessive use of biochar (>2) resulted in growth inhibition, probably due to nutrient imbalances. These results highlight the importance of biochar source and concentration for optimizing rice growth, even in hydroponic systems, and emphasize the potential of biochar amendments to support sustainable agricultural practices.

Keywords: Biochar; Plant growth; Pyrolysis; Soil-less cultivation; Sustainable Agriculture

GRAPHICAL ABSTRACT (GA)



Identification of Fast Pyrolysis Primary Products of Rice Straw by Using a Pyroprobe Integrated with an Ion Trap Tandem Mass Spectrometer

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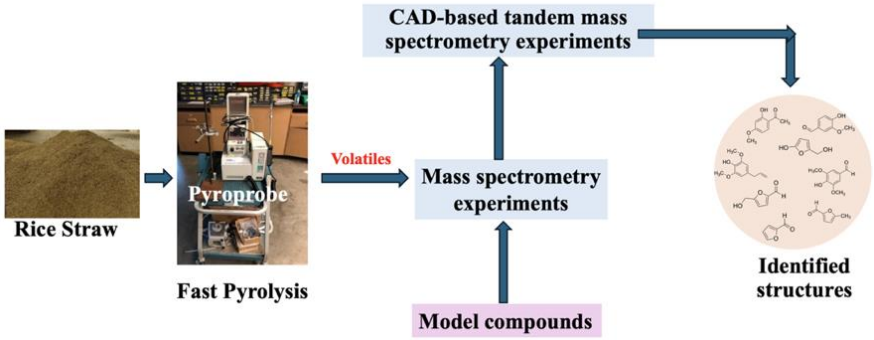
ABSTRACT

Burning of stubble, majorly consisting of rice straw, degrades the air quality index, even up to the severe category, in most north Indian cities. One of the attractive ways to manage rice straw is to subject it to fast pyrolysis to convert it into valuable solid, liquid, and gaseous products. The liquid product (bio-oil) has the potential to replace fuel and value-added chemicals currently derived from crude oil**.** However, several drawbacks are linked to its commercialization, such as high water content (15-30 wt.%), high oxygen content (30-60 wt.%), low heating value (15-30 MJ/kg), low pH (2-3). The development of analytical techniques to identify the chemical composition of the volatile pyrolysis products is necessary in order to be able to optimize methodologies for further refining of bio-oil into fuels or valuable chemicals. In this work, methodology was developed and employed to identify primary volatile products of fast pyrolysis of rice straw by employing a pyroprobe located inside an atmospheric pressure chemical ionization (APCI) source (operated in both positive and negative ion modes) of a tandem mass spectrometer. Methanol:water (50:50 v/v) and ammonium hydroxide:water (50:50 v/v) were used as a reagent and dopant, respectively. Tandem mass spectrometry (MS^2) experiments based on collision-activated dissociation (CAD) were employed to gain structural information for the most abundant ions generated from the pyrolysis products. Compounds derived from hemicellulose and cellulose degradation were detected by using positive-ion mode mass spectrometry. In contrast, lignin degradation compounds were detected by using negative-ion mode. The identification of the primary pyrolysis products can be used to delineate the reaction mechanisms for rice straw pyrolysis, which is needed to efficiently design and operate a medium-to-large scale pyrolysis reactor for rice straw.

GRAPHICAL ABSTRACT (GA)



Comparison of Conventional and Microwave-Assisted Pyrolysis for Biochar Production from Tea Waste

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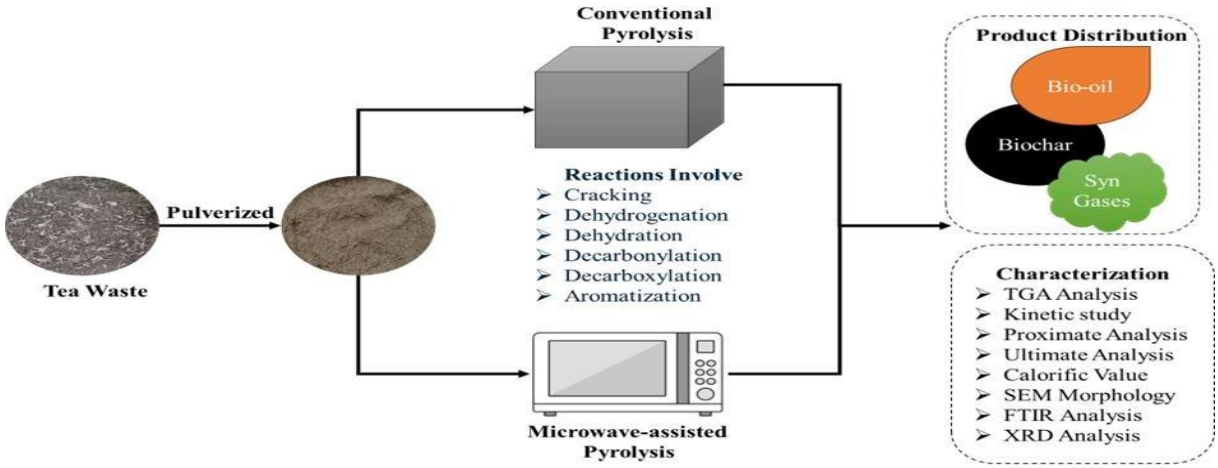
ABSTRACT

This study examines the rapid pyrolysis of tea waste utilizing two distinct pyrolysis techniques: traditional pyrolysis and microwave-assisted pyrolysis. The pyrolysis of tea waste was conducted using conventional pyrolysis at varying temperatures (400-600 °C) and microwave-assisted pyrolysis at 450W. The highest yields of bio-oil and biochar are 38 wt.% and 49.97 wt.%, respectively, at 400 °C, while the non-condensable gas output is 40.89 wt.% at 600 °C. The thermal degradation of discarded tea waste was observed using Thermogravimetric analysis (TGA) at three distinct heating rates: 10, 20, and 30°C/min in the temperature range (30-900 °C). The activation energy of the waste tea sample was determined utilizing various kinetic models: Flynn–Wall–Ozawa (FWO), Kissinger–Akahira–Sunose (KAS), and STARINK. The tea waste contains a high concentration of extractives and lignin, 31.17 and 29.16 wt.%, respectively. The physiochemical characteristics of biochar obtained from conventional pyrolysis and microwave-assisted pyrolysis were estimated and compared.

GRAPHICAL ABSTRACT (GA)



Optimization of Pyrolysis Process Parameters of Biochar Produced from Gulmohar Pods Through Response Surface Methodology

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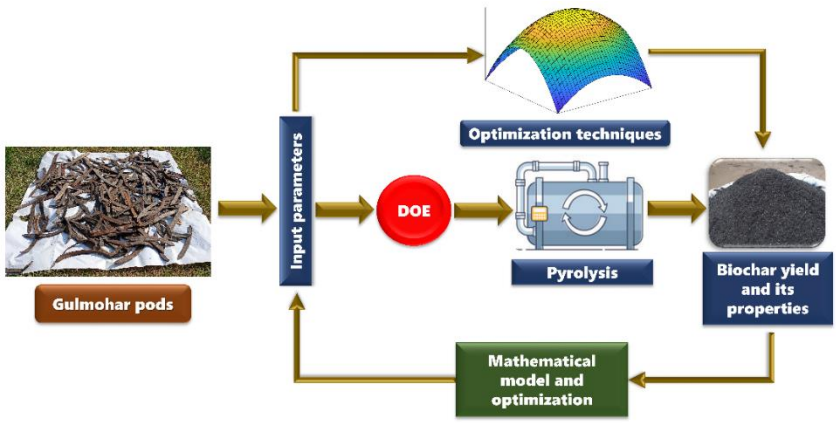
ABSTRACT

Extensive and rapid population growth, urbanization, and economic development in the country are degrading the land, surface, and groundwater resources through uncontrolled urban growth, industrialization, expansion and intensification of agriculture, destruction of natural habitats, and extensive and uncontrolled use of surface and groundwater resources. To protect soil and water while minimizing pollution, it's essential to implement cost-effective and sustainable practices. Biochar application is one such practice. Biochar is a carbon-enriched material that is produced by the thermochemical conversion of biomass. Due to its heterogeneous pore size and surface structure, biochar acts as a potential material for improving soil and water quality, carbon sequestration, adsorbing heavy metals, increasing growth and yield, and nutrient recycling. In this present study, the major pyrolysis process parameters, namely pyrolysis temperature and residence time, are optimized by using response surface methodology (central composite design) by taking different combinations of temperature and residence time for the biochar obtained from Gulmohar pods. The results obtained show that biochar yield increases towards lower values of temperature and residence time. However, elemental carbon content increases towards higher temperatures and residence time. The volatile matter also gets reduced towards higher temperatures and residence time. The maximized yield of biochar is computed at a temperature of 260 °C and 18 min residence time. The maximum elemental carbon was computed at a temperature of 471 °C and 83 min residence time. The minimum volatile matter content is computed at 539 °C and 103 min residence time. Hence, the optimal pyrolysis condition is obtained as the centroid of the three optimum points, which is 423 °C and 68 min, respectively.

GRAPHICAL ABSTRACT(GA)



Kinetics and Thermodynamic Analysis of Pyrolysis of Combustible Fraction of Municipal Solid Waste Using Model-Free Approaches

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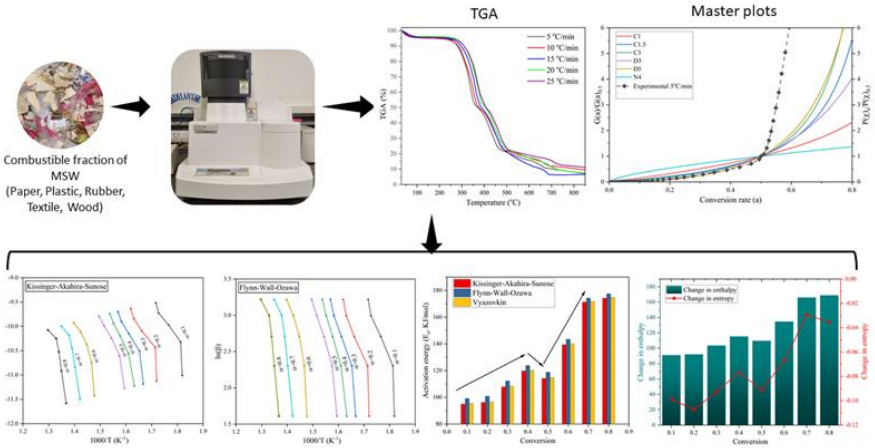
ABSTRACT

The pyrolysis of combustible fractions of municipal solid waste (CFMSW) can be a viable energy recovery and waste management strategy. However, the complex reaction involved in the process makes it difficult to understand the underlying decomposition mechanism and predict the final product yield. The kinetic and thermodynamic analysis of pyrolysis of CFMSW can provide valuable insights into the complex nature of reactions, energy consumed, and the spontaneity of the process. This study aims to predict the kinetic parameters (activation energy and pre-exponential factor) and the associated thermodynamic parameters (change in enthalpy, change in entropy, and Gibbs free energy) of the CFMSW pyrolysis using the model-free approaches (Kissinger-Akahira-Sunose, Flynn-Wall-Ozawa, and Vyazovkin advanced iso-conversional method). The pyrolysis of CFMSW is performed in a thermogravimetric analyzer at varying heating rates of 5,10,15,20, and 25 $^{o}Cmin^{-1}$ and temperatures ranging from 30-900 ^{o}C. We employed G(α) master plots to determine the best-fitting reaction model for the process. The best-fitted reaction model has been selected based on the quality of fit (%) values obtained for each model. The average apparent activation energy values were found to be 127, 131, and 128 KJ/mol using the Kissinger-Akahira-Sunose, Flynn-Wall-Ozawa, and Vyazovkin methods, respectively. The Criado master plots indicate that the overall pyrolysis process followed a 3rd-order reaction model. The evaluation of thermodynamic parameters suggests that the CFMSW pyrolysis is thermodynamically feasible due to the negligible energy gap (< 6 KJ/mol) between enthalpy change and apparent activation energy. The results from this study can be used for extensive modeling and process optimization of CFMSW-based pyrolysis reactors in the Indian scenario.

GRAPHICAL ABSTRACT (GA)



Co-Pyrolysis of Waste Low-Density Polyethylene and Waste Nitrile Gloves to Produce Liquid Fuel

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ABSTRACT

Pyrolysis is a promising strategy for managing waste materials like low-density polyethylene (LDPE) and waste nitrile gloves (WNG). Both LDPE and WNG are widely used in medical, industrial, and consumer applications, however, the disposal of these materials poses significant environmental and health risks due to their non-biodegradable nature and potential for toxic leachate. Co-pyrolysis, a thermal decomposition process without oxygen, converts these waste polymers into valuable by-products like liquid fuels, carbon char, and industrial-grade gases. This process reduces hazardous chemical content and volume while addressing plastic pollution and waste accumulation, supporting sustainable waste management practices, and circular economy principles, besides decreasing the ecological footprint of synthetic polymer disposal. Following this, thermal co-pyrolysis of LDPE and WNG was performed in a 450-600 °C temperature gradient using a fixed-bed batch reactor keeping the heating rate at 20 °C /min. The ratios were varied along with the temperature to obtain the maximum quantity of liquid oil while minimizing the gases and char amount. Proximate, Elemental and Thermogravimetric analyses of the input feed confirmed the presence of minimal moisture and high content of volatile matter in the feedstock, prerequisites for selecting the feed to produce renewable fuel. A minimum quantity of leftover solid char was obtained, proving the efficiency of the process, however, the solid char could be a matter of further research. The present study demonstrated that the co-pyrolysis of waste LDPE and WNG may be used to obtain renewable liquid fuel, suitable for utilisation in various other applications.

Keywords*:* Co-pyrolysis; Low-density polyethylene; Proximate analysis; Thermogravimetric analysis; Waste nitrile gloves

GRAPHICAL ABSTRACT (GA)

Valorization of Waste Streams: Biochar Production from Paper Sludge, Camel Dung, and Food Sludge via Microwave Pyrolysis

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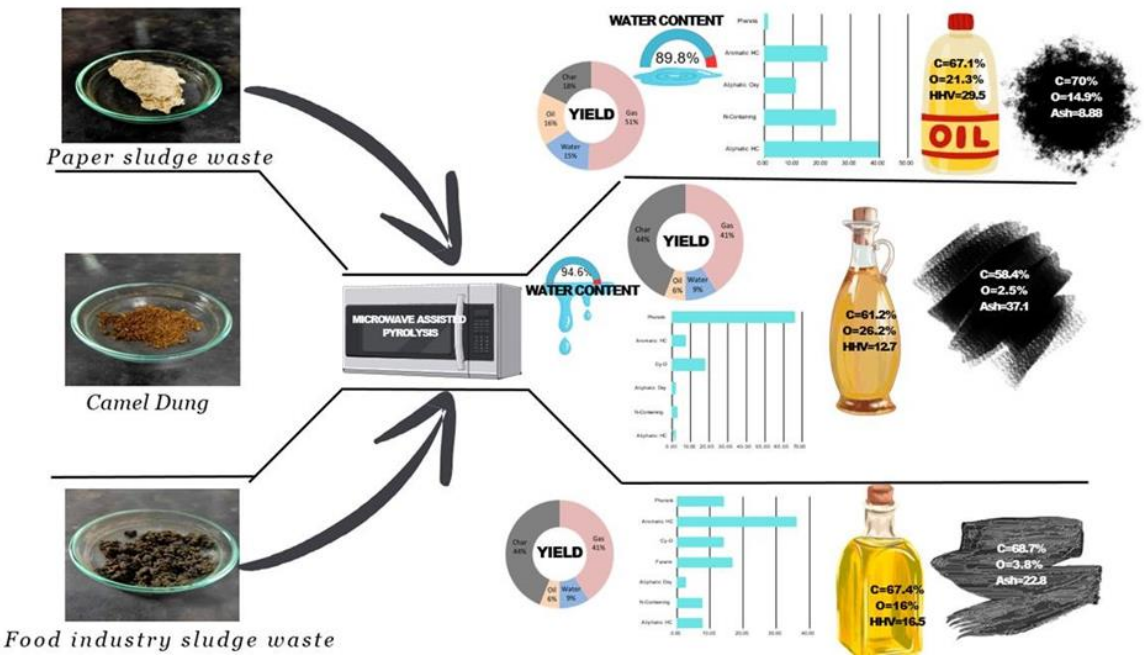
ABSTRACT

Microwave pyrolysis of three waste streams mainly paper sludge waste (PSW), Camel dung (CD) and food sludge waste (FSW) were conducted to investigate the potential for biochar production from these wastes. The extensive feedstock characterization was carried out including ultimate analysis, proximate anlaysis, HHV analysis, thermogarvimetric analysis and ash composition. Intial studies were carried out at 600 W-600 °C and product yield and compositions were evaluated. The thermal decomposition of feedstock follows a trend: PSW (356 °C) > CD (317 °C) > FSW (302 °C). The heating rate (°C min^{-1}) of the feedstock follows the trend: FSW (43.4) > PSW (33.4) > CD (25.1). FSW contains the highest char (49 wt.%) and PSW contains the minimum char (18 wt.%). The gas yield was highest (51 wt.%) from PSW. CD contains high amount of phenols (71%) while PSW contains higher aromatic hydrocarbons (40%). Though PSW and FSW were rich in long chain aliphatic hydrocarbons and aromatic hydrocarbons (mainly PAH's) respectively they produced equal oil yield. Highest HHV for FSW can be attributed to higher H/C ratio of FSW. FSW comprised an abundance of water content, however CD had the least organic phase encompassed in its aqueous phase (~ 5%). Almost all the char samples exhibited a neutral pH (from 7.2-8).

GRAPHICAL ABSTRACT (GA)



Valorization of Individual Citrus Peels Through Anaerobic Digestion and Pyrolysis

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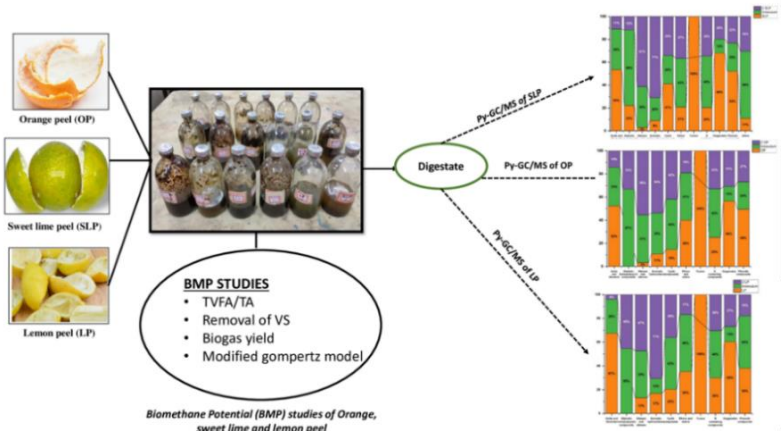
ABSTRACT

Globally, the major contributors to food waste are households (61%), food service industries (27%), and retail (12%). In this study we aim to integrate Biomethane potential (BMP) and py-GC/MS experiments conducted on individual citrus peels (lemon peel, orange peel, and sweet lime peel) at inoculum to substrate ratio of 2 (ISR:2), pyrolyzing the digestate using py-GC/MS. The experimental results of anaerobic digestion of citrus peels showed volatile solids removal of 61% for orange and sweet lime peels and the removal efficiency of lemon peels is 44.5% only. TVFA/TA, the ratio between (TVFA) and total alkalinity(TA), ranges between 0.1-0.16, showing stable anaerobic digestion performance and process stability. The biogas yield is high for orange peels 262 ml/gVS, followed by sweet lime peels of 194.2 ml/gVS, and low for lemon peels 61.2 ml/gVS. The modified Gompertz model is applied for all individual citrus peel experiments, and R^2 values (more than 0.9) are determined, indicating that the predicted and experimental values are close to each other and thus determining the biogas yield rate and lag phase from the model. TGA analysis of the digestate of individual peels experiments shows the mass loss is more significant in the zone 85 ℃ -150 ℃ for LP (21.4%) and equal for the other two peels corroborating with the AD results. The weight loss percentage in the devolatilization zone of all three peels is between (11% -14%). The py-GC/MS of all the individual peels contain furans (12-19%), acids and alcohols (21-33%), oxygenates (16-20%), and phenolic compounds (7-17%). Upon pyrolysis of the digestate of all individual peels, higher aromatic hydrocarbon fractions (54-71%) are found in ISR 2 of all digestates with the reduction in acids, alcohols, and furans. N-containing compounds have shown almost similar percentages in the individual peels, and a slight decrease in its presence was noted in ISR 2 digestates.

GRAPHICAL ABSTRACT (GA)



Biomethane Potential (BMP) studies of Orange, sweet lime and lemon peel

Sustainable Production of Biopolymer Precursor from Waste Biomass Derived Sources for Circular Economy

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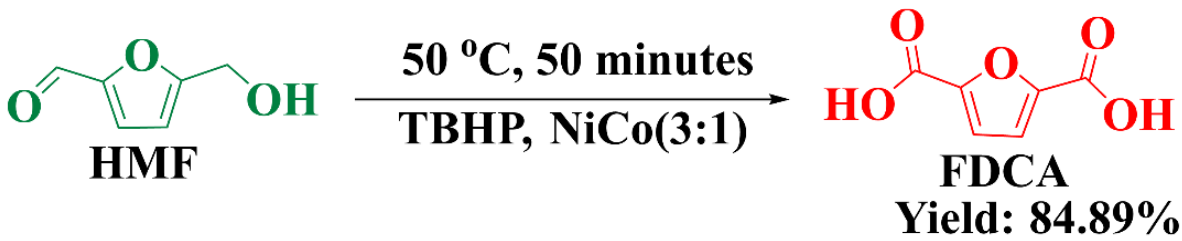
ABSTRACT

This study reports the development, characterization, and application of NiCo bimetallic catalysts for producing 2,5-furandicarboxylic acid (FDCA) through the oxidation of waste biomass sources such as 5-hydroxymethylfurfural (HMF). FDCA is an essential biopolymer precursor that could replace terephthalic acid (TPA). The NiCo catalysts were prepared using a co-precipitation technique with varying Ni to Co molar ratios and then calcined in a muffle furnace. The NiCo (3:1) catalyst achieved complete conversion of HMF and yielded up to 84.89% FDCA at 50 ℃ in 50 minutes. This report also explored the reaction parameters such as catalyst quantity, temperature, reaction time, quantity of base, and oxidant amount on FDCA yield. The NiCo (3:1) catalyst demonstrated minimal activity loss over at least five cycles. Better catalytic activity can be attributed to the synergistic effects of the bimetallic catalyst and the presence of higher concentration of lattice oxygen. Characterization techniques, including BET, XRD, H_2-TPR, CO_2-TPD, HR-TEM, and XPS were carried out to analyze the catalysts' properties and performance. Reaction products were quantitatively assessed via HPLC and qualitatively via HR-MS.

Keywords: 2,5-furandicarboxylic acid; 5-hydroxymethylfurfural; Bimetallic catalyst; Lattice oxygen; Tert butyl hydroperoxide

GRAPHICAL ABSTRACT (GA)



A Comparative Assessment of Hydrothermal Liquefaction and Pyrolysis Process for Woody Biomass Valorization to Liquid and Solid Fuels

Srinivasan Santhosh[1], M. V. Pragadeshwar Babu[1], Ravikrishnan Vinu[1,*]

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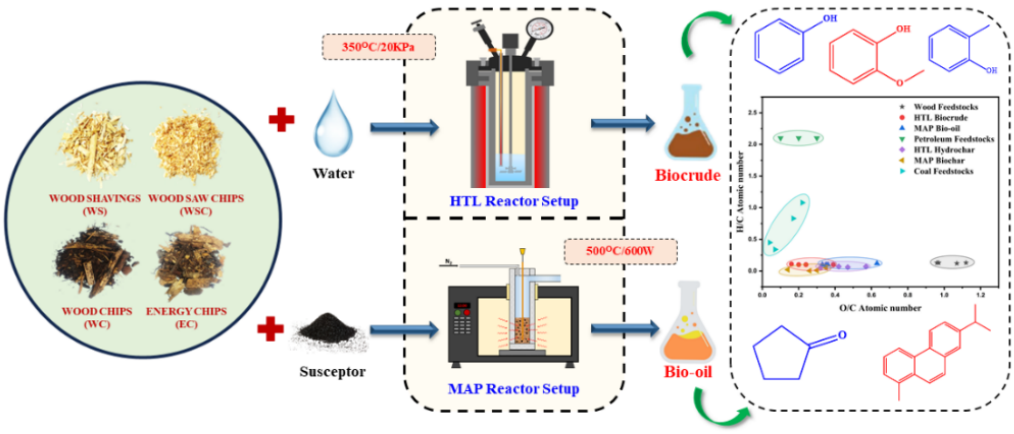
ABSTRACT

The conversion of biomass into biofuels, chemicals and biomaterials is gaining increasing attention for sustainable development. Microwave-assisted pyrolysis (MAP) and Hydrothermal liquefaction (HTL) are two advanced technologies that have emerged as promising methods for valorizing biomass. These technologies can produce a broad range of reaction products that are useful in the energy, pharmaceutical, and chemistry sectors. This study compares the effects and challenges in the valorization of woody biomass using HTL vs MAP and their impacts on the reaction conditions, such as temperature, time, biomass type and loading, and microwave power, on the yields and properties of reaction products. The experiments were conducted on woody biomass of two different sizes to see how particle size affects the production of bio-oil. The microwave-assisted pyrolysis of woody biomass was carried out at a temperature of 500 °C and a power output of 600 W, with an N_2 flow rate of 100mL/min. Hydrothermal liquefaction of woody biomass was performed at 300 °C, 350 °C, and 400 °C. The results show that microwave pyrolysis generates a higher bio-oil yield of 35% due to its uniform and volumetric heating, compared to the 22% oil yield from HTL at 350 °C. The main objective of this research is to identify significant chemical differences between HTL and MAP (bio-oils, biochar, gas and aqueous phase) that could explain variations in their thermal behaviour. Analytical techniques such as elemental analysis, KFT, proximate analysis, bomb calorimetry, Ion chromatography and Gas analysis (GC-TCD/FID) have been used to evaluate the overall composition of the fraction, and GC-MS has been used to study the composition of organic monomers. The study also compares energy consumption and recovery in microwave-assisted pyrolysis and hydrothermal liquefaction of woody biomass.

GRAPHICAL ABSTRACT (GA)



Co-Gasification of Rice Husk and Cashew Nut Shell at High Temperature and Pressure in A Dynamic Environment of Steam, Air, And Nitrogen in A Downdraft Fixed Bed Reactor

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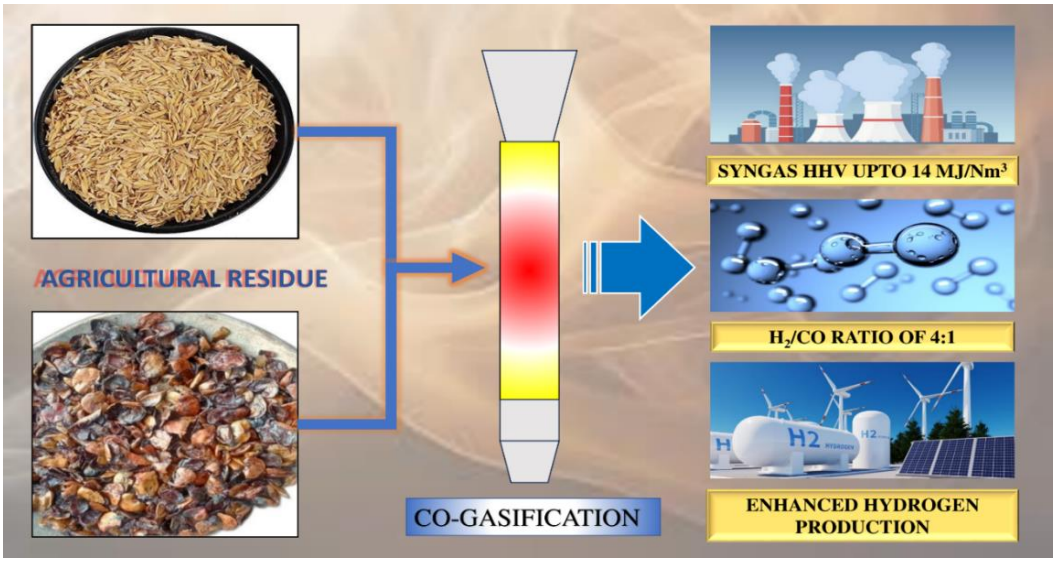
ABSTRACT

With the depletion of energy resources like coal, dependence on cleaner energy carriers like biomass is growing in the present century. Gasification is the most renowned and efficient technology for extracting this energy via the generation of syngas, which produces power, valuable chemicals, and transportation fuels. Rice husk and cashew nut shells are the two abundant biomasses predominantly found in India with extensive energy potential. Rice husk and cashew nut shells have several disadvantages when gasified alone. The disadvantages are eliminated when gasified together, e.g., co-gasification can reduce the tar and ash content, which can cause serious operational issues during gasification. Rice husk with high lignin content and cashew nut shell with high volatile matter are ideal feedstocks for syngas production with enhanced hydrogen content via gasification. The present study investigates the synergistic effect of co-gasification of the above feedstocks. The mixture of rice husk and cashew nut shell with a blending ratio of 75:25 and 50:50 is gasified using the mixture of steam, air, and nitrogen at 850 °C. Syngas with an energy content (Higher heating value) of 14 MJ/Nm^3 is produced with gasification of 50:50 blending, while a high H_2/CO ratio of 4:1 is achieved when 75:25 blending is gasified.

Keywords: Cashew nut shell; Co-gasification; Nitrogen; Rice husk; Steam; Syngas

GRAPHICAL ABSTRACT (GA)



Fabrication of Peroxidase Mimic Fe_3O_4/Biochar Nanocomposite from Spent Mushroom Substrate

Ashmita Das[1], Ramgopal V S Uppaluri[1,2], Sudip Mitra[1,*]

[1]School of Agro and Rural Technology, Indian Institute of Technology Guwahati, Assam, India
[2] Department of Chemical Engineering, Indian Institute of Technology Guwahati, Assam, India

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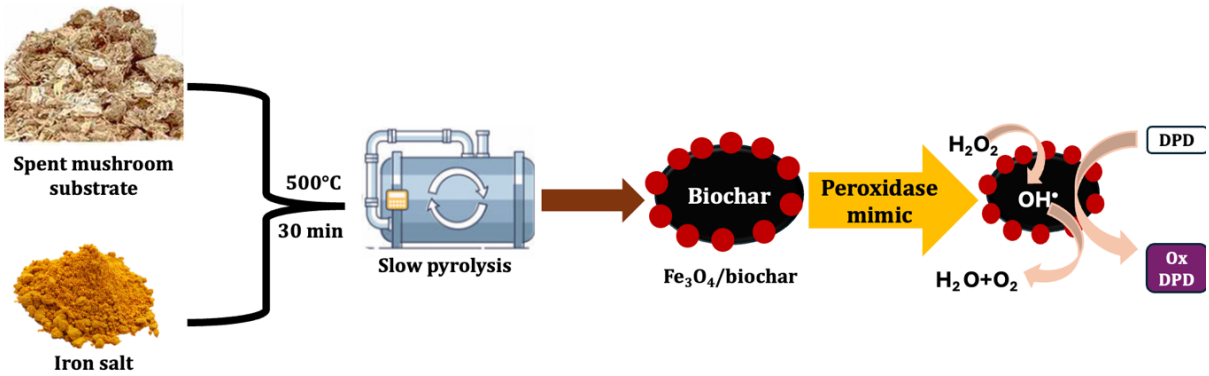
ABSTRACT

The cultivation of edible mushrooms for commercial purposes has recently gained significant attention due to the increased demand for nutrient-dense food. However, it is important to develop an environmentally friendly strategy for handling the large amount of leftover mushroom substrate (SMS) obtained during the post-harvest phase, rather than simply disposing of it or burning it in the open atmosphere. In this current study, Fe_3O_4/biochar was developed by the slow pyrolysis of iron pretreated SMS at 500 °C for 30 min. The prepared nanozyme is further characterized using FESEM, EDS, and XRD. The EDS and XRD study confirms the presence of Fe_3O_4 on the surface of the biochar. The FESEM study also confirms deposition of Fe_3O_4 nanoparticle on the surface of the biochar. The peroxidase mimic catalytic activity of the biochar is further evaluated using Diethyl-p-phenylene diamine (DPD). The material showed adequate affinity towards both DPD and hydrogen peroxide. The peroxidase mimic catalytic activity of the nanocomposite was further utilized for the colorimetric detection of hydrogen peroxide. "The catalytic ability of the nanocomposite makes it a sustainable alternative to natural enzymes."

GRAPHICAL ABSTRACT (GA)



Effect of Different Susceptors on Product Distribution in Microwave-Assisted Pyrolysis of Coconut Shell Biomass

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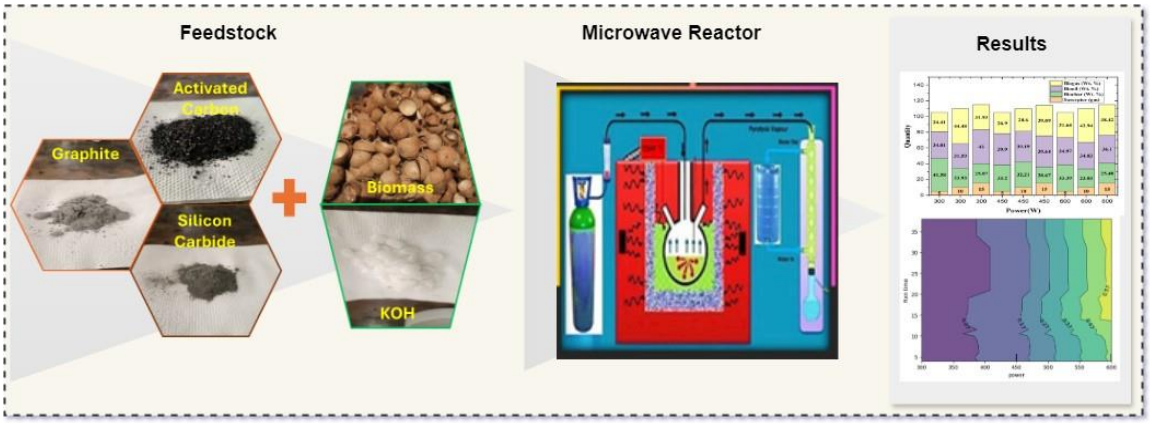
ABSTRACT

This study investigates the effect of different susceptors on microwave-assisted pyrolysis (MAP) of waste coconut shells for biochar production. Coconut shells were ground into powder and subjected to pyrolysis at power levels of 300, 450, and 600 W with temperatures maintained between 600-650 °C. KOH served as a catalyst, and three susceptors-graphite, silicon carbide, and activated charcoal were tested to assess their influence on product yields. The use of susceptors, especially activated charcoal, tends to favor bio-oil production at higher power levels (450 W and 600 W), while bio-char yield decreases. Graphite and silicon carbide show a more balanced increase in bio-oil and bio-gas production but still reduce bio-char yields compared to the control (no susceptor). The dielectric properties of biochar were analyzed using an Impedance Analyzer, showing that graphite had the highest absorption capacity, leading to faster heating rates and shorter reaction times. To model the complex pyrolysis process, machine learning models were employed. The model was developed using an experimental dataset that included biomass quantity, microwave absorber quantity, and reaction conditions as input variables, with product yields as the target variables. Three machine learning models such as Gradient Boosting Regressor, Random Forest Regressor, and Support Vector Regressor were used to model the process. The Random Forest Regressor demonstrated the best prediction performance.

Keywords: Biochar; Biomass; Machine learning; Microwave Assisted Pyrolysis; Susceptor

GRAPHICAL ABSTRACT (GA)



Bayesian Optimization of Microwave-assisted Copyrolysis of Biomass and Plastic

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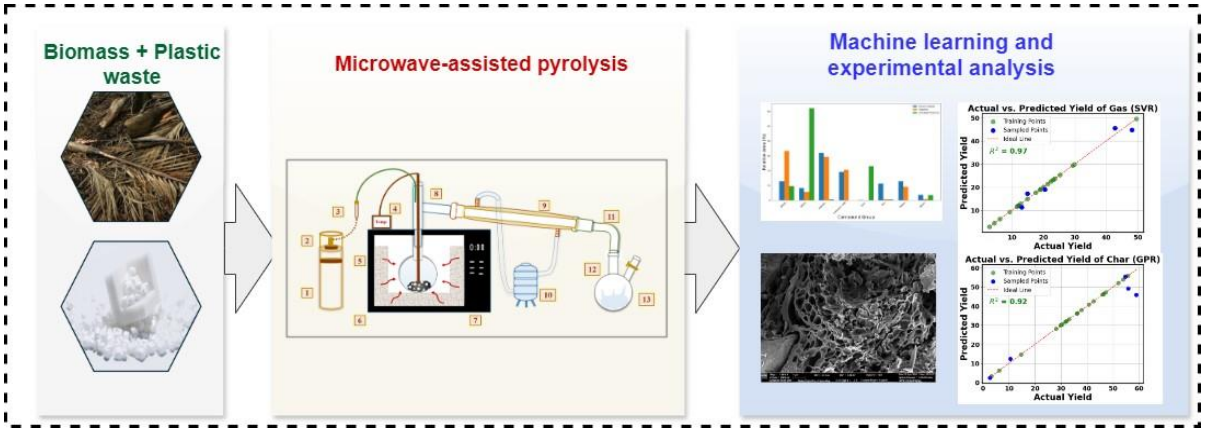
ABSTRACT

The co-pyrolysis of plastic and biomass with microwave assistance presents a sustainable waste management solution, generating valuable products such as biochar, bio-oil, and biogas. With increasing concerns over plastic waste, co-pyrolysis emerges as a preferred alternative to landfilling and open dumping. The aim of the study is to optimize pyrolysis conditions, including temperature, time, and material ratios, to maximize product yields. Supervised machine learning techniques such as Gaussian Process Regression (GPR), Support Vector Regression (SVR), and Extreme Gradient Boosting (XGB) are employed to predict product yields (oil, gas, and char) with high accuracy, achieving R^2 values ranging from 0.71 to 1.00 on test sets. Among the models, SVR demonstrated superior performance for predicting oil yield with an R^2 of 1.00, while GPR and XGB showed strong predictive power for gas and char yields. To further enhance model performance, Bayesian optimization was applied to fine-tune hyperparameters of the best-performing models, improving model robustness and reducing error metrics such as MAE and RMSE. This optimization led to highly accurate predictions with minimized errors (MAE as low as 0.008 for oil yield using SVR). The results indicate that machine learning, in conjunction with Bayesian optimization, provides an effective framework for optimizing microwave-assisted co-pyrolysis processes, paving the way for improved resource recovery and sustainable waste valorization.

Keywords: Bayesian optimization; Biomass; Machine learning; Microwave assisted pyrolysis; Plastic waste

GRAPHICAL ABSTRACT (GA)



PYROASIA 2024
International Symposium on Analytical and Applied Pyrolysis

Numerical Simulation of Microwave Assisted Catalytic Pyrolysis of Biomass for Fuel Production

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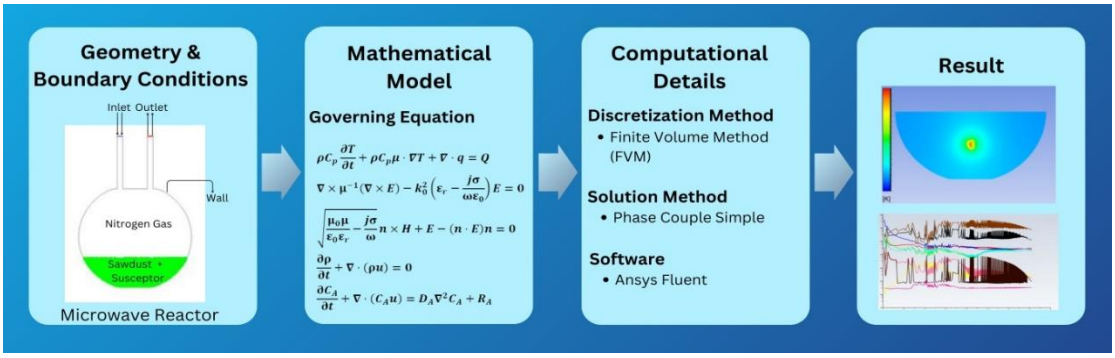
ABSTRACT

Microwave-assisted pyrolysis (MAP) is a promising approach for biomass valorization, offering enhanced energy recovery and sustainable fuel production. In this study, a comprehensive mathematical model is developed to simulate biomass pyrolysis in a MAP system using ANSYS Fluent. The model incorporates a lumped kinetic scheme to predict the formation of key pyrolysis products such as gases, bio-oil, and biochar while accounting for the coupled effects of microwave heating, heat transfer, and fluid flow governed by Darcy's law. The sawdust and susceptor mixture along with the nitrogen gas are modelled using Multi-Fluid Model (MFM). The rheological properties of solid phases are obtained from Kinetic Theory of Granular Flow (KTGF). The reactions are modelled using Arrhenius equations. Transient numerical analysis is conducted to explore the spatial distributions of the temperature, and yields of biochar and gases within the pyrolysis reactor. The effects of critical parameters, such as microwave power input, gas flow rate, biomass particle size, and susceptor mass, are examined in detail. Results indicate that higher microwave power enhances electric field intensity, leading to rapid heating and increased temperature uniformity, which accelerates the pyrolysis process. Similarly, increasing gas inlet velocity can reduce the residence time, leading to incomplete conversion of intermediates and lower product yields. The findings demonstrate that MAP is a viable and efficient method for biomass conversion, particularly for sawdust, highlighting its potential in advancing renewable energy technologies.

Keywords: Biomass; Computational Fluid Dynamics; Kinetic Theory of Granular Flow; Microwave Assisted Pyrolysis; Multi-Fluid Model

GRAPHICAL ABSTRACT (GA)



Exploring Sludge Biochar as a Soil Amendment: Characterization and its Impact on Indian Mustard Growth and Rhizospheric Microbial Community

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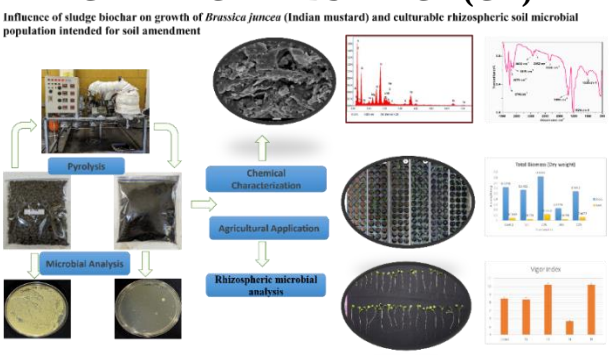
ABSTRACT

This study aimed to explore the impact of adding sludge biochar to soil on the growth of mustard plants and the population of microorganisms in the rhizosphere. The physicochemical properties of biochar and the effect of dried sludge as well as sludge biochar on the microbial community were also studied. TGA analysis showed biochar's thermal stability up to 500 °C. XRF analysis indicated enrichment of phosphorus and potassium in biochar, making it valuable for agricultural purposes. FTIR analysis revealed surface functional groups that efficiently bind cationic heavy metals, enhancing their potential for environmental remediation. FESEM-EDS confirmed a microporous structure and high carbon content, which contribute to its suitability for carbon sequestration and soil improvement. The study found that biochar in the absence of plants significantly enhanced the microbial activity in soil (10% enhancement in CFU). Similarly, the addition of sludge biochar to soil significantly increased the growth of mustard plants (a 15% increase in seedling growth along with a 20% enhancement in total chlorophyll content). Metabolite profiling of shoot extracts revealed differing compound relative abundance, fatty acid esters were dominant, ranging from 69.53% (T1) to 76.96% (T3). In root extracts, fatty acids and esters prevailed, with T1 exhibiting the highest percentage at 88.37%. The population of culturable bacteria specifically the colonies that appeared on the nitrogen-free medium were significantly enhanced in the rhizospheric soil. The results thus suggest that sludge biochar has the potential to improve soil quality, promote the growth of beneficial microorganisms, and enhance plant growth and phytochemicals.

GRAPHICAL ABSTRACT (GA)



Green Production of Aviation Fuel Blend, Butyl butyrate using Silicotungstic AcidCatalyst

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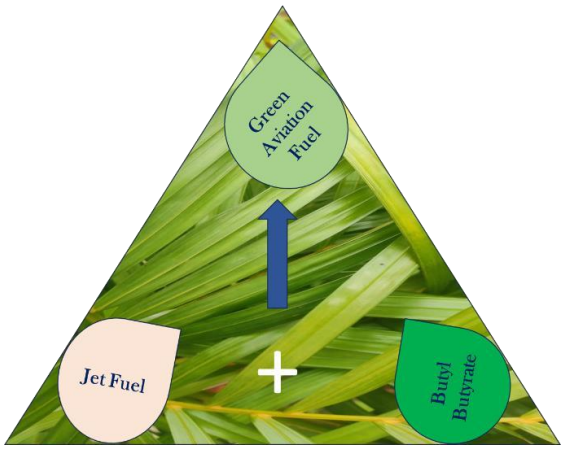
ABSTRACT

The aviation industry has drawn greater attention worldwide due to its considerable greenhouse gas emissions and reliance on traditional petroleum jet fuel. Using biomass fuels as a substitute for conventional jet fuel has drawn significant attention. One prospective jet fuel blend is butyl butyrate (BB), produced from bio-renewable resources. It can lower CO_2 emissions throughout its lifespan, making it a desirable substitute for aviation fuel blends. This study investigated butyl butyrate synthesis as a potential green bio-aviation fuel blend using a silicotungustic acid catalyst. The catalyst is a promising option for sustainable bio-aviation fuel because of its high activity, stability, and environmental friendliness. Optimizing reaction parameters, including temperature, reaction time, catalyst loading, and reactant molar ratios, was the prime focus of the experimental study. Several reactions were conducted under varied conditions to evaluate the conversion of butyric acid and the selectivity towards butyl butyrate. The results demonstrated that the silicotungustic acid catalyst exhibited exceptional catalytic activity for the esterification process. The greatest conversion of butyricacid was reached at 100 °C. In optimal circumstances, there was a significant increase in selectivity towards butyl butyrate. The butyl butyrate product was quantified using GC. The catalyst was characterized using FTIR, NH3 TPD, XRD, XPS, SEM, and TEM. The widespread use of bio-jet fuelshas substantial promise for reducing CO_2 emissions and producing bio-jet fuel, which is contingent on future biomass feedstock availability.

Keywords: Bioaviation fuel; Butyl butyrate; Butyric acid; GHG emissions

GRAPHICAL ABSTRACT (GA)



Recycling Waste Wind Turbine Blades Using Pyrolysis

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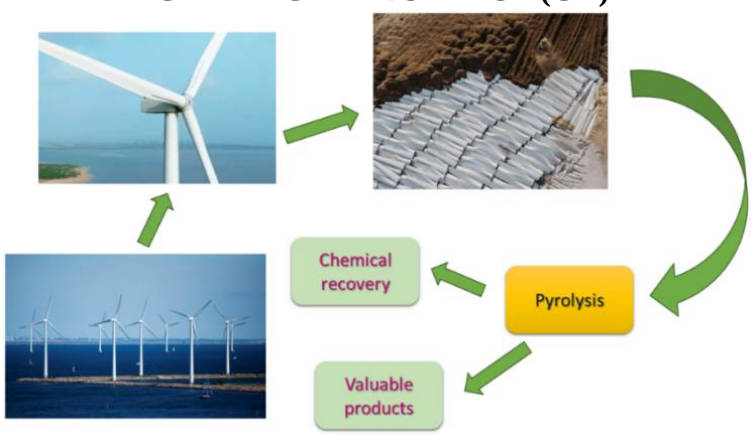
ABSTRACT

Renewable energy plays a pivotal role in reaching sustainable development goals such as "Affordable and clean energy" and "Climate action". Wind energy is a well-developed form of renewable energy that is widely used for the generation of electricity throughout the world. In order to meet the rising energy demand of the world, it is essential to increase renewable energy production, and windmills play an important role in it. Blades of wind turbines have an expected life of 20-25 years; after which they have to be replaced. The generation of waste wind turbine blades is increasing, and it is essential to recycle them for a circular economy. However, the wind turbine blade is a composite material made of several components such as epoxy resins, glass fibers, polymeric foam made of polyethylene terephthalate, polyurethane, etc., and it is difficult to separate them. Among various disposal methods, pyrolysis helps in providing resource recovery and various valuable products. Analytical pyrolyzer hyphenated with Gas chromatography and mass spectrometry (Py-GC/MS) serves as an important tool and method to study the kinetics, reaction mechanism, and product distribution. In this study, the windmill blade sections procured from various sources were pulverized and characterized using a range of techniques like thermogravimetric analysis (TGA), proximate analysis and elemental analysis. The blades exhibited significant difference in their basic constituents and elemental composition. For example, older blades had a polyurethane foam and balsa wood in their framework, while recent models do not contain them. The samples were further subjected to pyrolysis using single shot Py-GC/MS and thermal desorption followed by Py-GC/MS (TD/Py-GC/MS). The effects of temperature and additives on product distribution are extensively studied. More interesting results on the recovery of epoxy monomers, phenols and their yields will be discussed. The results suggest that pyrolysis has the potential for recovering high-value chemicals from the waste wind turbine blade.

GRAPHICAL ABSTRACT (GA)



Waste to Alternate Energy Resources from Biomass Pyrolysis

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ABSTRACT

Biomass pyrolysis is a thermochemical conversion process that decomposes organic material at elevated temperatures (300–700 °C) in the absence of oxygen, producing three primary products: biochar, bio-oil, and syngas. This process offers a sustainable and versatile solution for waste biomass valorization, enabling the production of renewable energy, valuable chemicals, and a stable form of carbon that can be used for carbon sequestration. The distribution and characteristics of the pyrolysis products depend on several factors, including feedstock type, pyrolysis temperature, heating rate, and residence time. Slow pyrolysis, which operates at lower temperatures and longer residence times, prioritizes biochar production with yields typically around 30–50%. In contrast, fast pyrolysis, which involves rapid heating and short residence times, maximizes bio-oil production, with yields up to 60–75%. The environmental and economic benefits of biomass pyrolysis are substantial. It addresses issues such as agricultural waste disposal, land degradation, and climate change mitigation. Additionally, the use of pyrolysis-derived products can reduce dependency on non-renewable resources and promote sustainable agricultural practices. However, the widespread adoption of biomass pyrolysis faces challenges, including feedstock variability, process optimization, and economic feasibility at commercial scales. Ongoing research focuses on improving pyrolysis technology through advanced reactor designs, catalytic upgrading of bio-oil, and the development of integrated biorefineries. Overall, biomass pyrolysis represents a promising pathway for converting waste biomass into valuable products while contributing to a circular economy and supporting global carbon neutrality goals.

GRAPHICAL ABSTRACT (GA)

Sustainable Valorization of Macroalgae Biomass: Conventional Pyrolysis and Hydrothermal Carbonization Approaches

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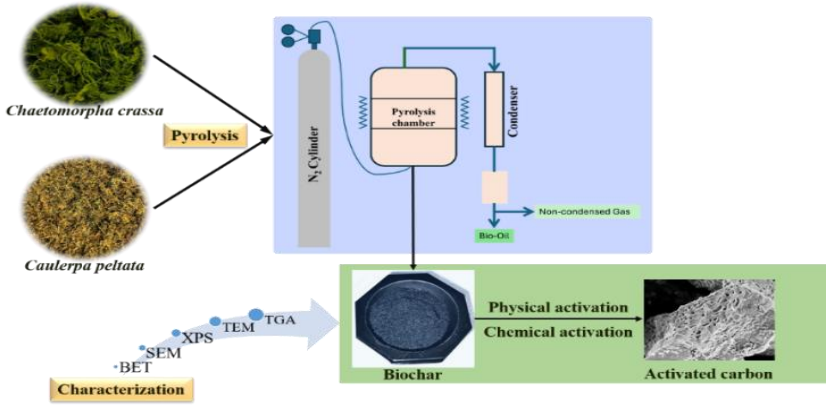
ABSTRACT

The increasing interest in sustainable waste management and renewable resources has led to the exploration of biochar derived from macroalgae biomass, as a promising material for environmental applications. This study explores the activation and characterization of biochar produced from two green macroalgae biomass *Caulerpa pelata,* and *Chaetomorpha crassa* via pyrolysis. Pyrolysis was conducted at varying temperatures (450-650 °C), residence time (1 h-3 h), and heating rate (5 °C/min-25 °C/min) to optimize the yield and properties of the resulting biochar. Chemical activation using agents like KOH and H_3PO_4 significantly increases surface area and enhances the adsorption capacity of heavy metals and organic contaminants. Physical activation methods were also evaluated to improve biochar's structural integrity and functionality, Comprehensive characterization techniques, including SEM, FTIR XRD, XPS, and BET surface area analysis, were used to assess the morphological, chemical, and surface characteristics of the biochar. The results confirm the successful modification of functional groups and surface characteristics, contributing to improved adsorption properties. In addition, the elemental analysis showed a reduction in oxygen content and an increase in carbon content, indicative of a more stable carbonaceous material with hydrophobic characteristics. This research highlights the influence of pyrolysis reaction conditions and activation techniques on the physicochemical properties of biochar, providing insights into optimizing biochar production from macroalgae biomass for applications in environmental remediation and biogas adsorption.

Keywords: Activated char; Biochar activation; Green macroalgae; Macroalgae biochar; Pyrolysis

GRAPHICAL ABSTRACT (GA)



Microwave Pyrolysis for the Synthesis of Hierarchical Porous Carbon Using Green Chemicals for Enhanced Energy Storage

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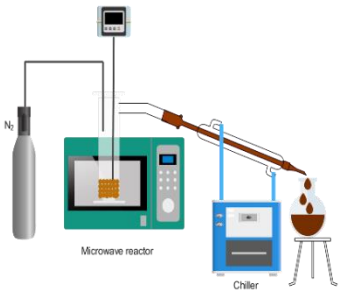
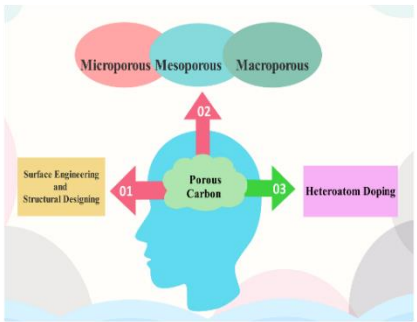
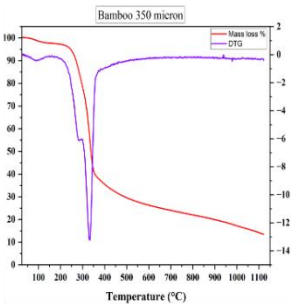
ABSTRACT

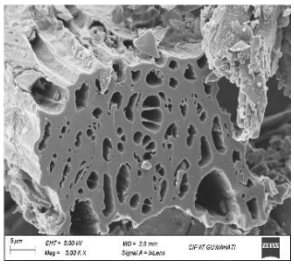
Bamboo-derived hierarchical porous carbon (BPC) for energy storage has gained attention due to its sustainability and abundance. This study compares conventional and microwave-assisted pyrolysis techniques for synthesizing porous carbon using green chemicals. Microwave pyrolysis, characterized by rapid heating, offers a more efficient route than traditional methods. Both methods produce high-surface-area porous carbons, essential for supercapacitor applications. This study uses a green chemical activation strategy to produce porous carbon for energy storage. The produced characterization techniques were employed to understand the material properties. CHNS analysis determined the elemental composition of carbon, hydrogen, nitrogen, and sulfur. FESEM and FETEM revealed the surface morphology and internal structure at micro- and nanoscale resolutions. BET analysis provided surface area (>1000 m^2/g) and pore distribution data, confirming the hierarchical nature of the material. XRD identified the crystallinity of carbon, while Raman spectroscopy assessed graphitic and disordered carbon phases. These techniques together demonstrate the potential of bamboo-derived porous carbon for efficient energy storage systems.

GRAPHICAL ABSTRACT (GA)









Effects of Temperature and Duration of Pyrolysis on Properties of Biochar Derived from *Erythrina indica* Biomass

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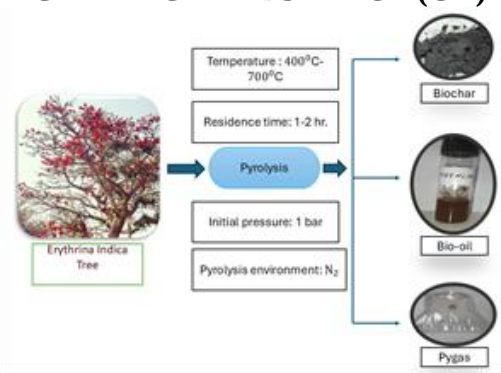
ABSTRACT

Biochar is a carbon-rich solid formed from the thermal decomposition of biomass in the absence of oxygen. The productivity of biochar relies on feedstock type and pyrolysis conditions. This study investigates the effects of varying pyrolysis temperatures and duration of pyrolysis on thermal decomposition of *Erythrina indica* biomass. Pyrolysis experiments were conducted in a fixed-bed reactor in a nitrogen environment at temperatures ranging from 400 °C to 700 °C and time from 60 to 120 minutes. Following pyrolysis, the resulting pyrolytic products underwent a comprehensive characterization employing advanced analytical techniques. This characterization aimed to elucidate the chemical composition, structural properties, and thermal behavior of the produced biochar and bio-oil. Techniques such as Fourier-transform infrared spectroscopy (FTIR) elucidated molecular functional groups, x-ray diffraction (XRD) provided insights into crystalline structure, scanning electron microscopy (SEM) offered observations of surface morphology, thermogravimetric analysis (TGA) revealed thermal stability profiles and energy dispersive x-ray (EDX) spectroscopy determined elemental composition, nuclear magnetic resonance (NMR) spectroscopy was specifically applied to the bio-oil, providing detailed insights into its composition. The results demonstrated that significant variations in biochar, bio-oil and pygas yields against the process conditions. By examining the resultant products in detail, valuable insights were gained into the transformation of biomass waste into biochar, crucial for tailoring biochar properties for specific applications. These findings highlight the critical influence of pyrolysis conditions on the outputs and suggest optimal conditions for maximizing biochar yield while balancing the production of valuable co-products.

Keywords: Biochar; Characterization; *Erythrina indica*; Pyrolysis; Temperature; Time

GRAPHICAL ABSTRACT (GA)



Thermal Recycling of GFRP: Fiber Recovery via Pyrolysis and Combustion

Sachin Kuriachan E[1*], Nelson Muthu[2], Pankaj Tiwari[1]

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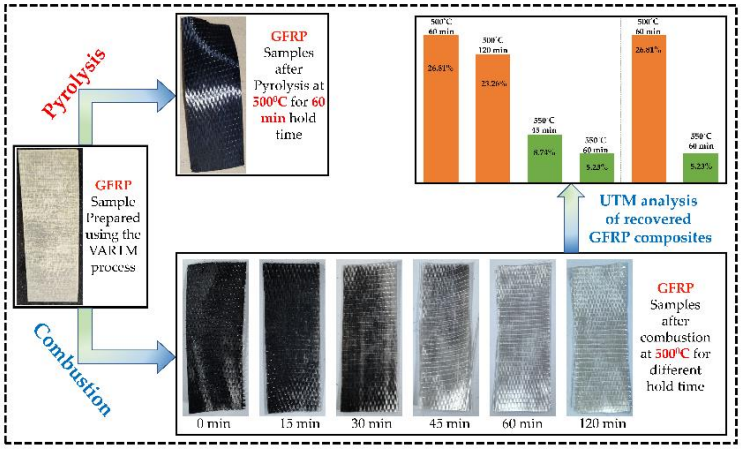
ABSTRACT

Glass fiber-reinforced polymer (GFRP) composites are widely utilized in industries such as wind energy, automotive, consumer goods, and construction due to their exceptional properties. However, the disposal of end-of-life (EOL) GFRP poses environmental concerns, necessitating the development of sustainable recycling methods for fiber recovery. Current recycling techniques include mechanical, thermal, and chemical approaches. The current study focuses on thermal recycling as a potential method for recovering glass fibers from GFRP composites. Several lab-scale experiments were conducted to recover fibers while retaining the maximum possible tensile strength. The process involved chemical pretreatment, followed by thermal steps (pyrolysis/combustion), and post-treatment. Chemical pretreatment reduced the pyrolysis end temperature by approximately 90 °C. However, pyrolysis left carbon residues on the fiber surfaces, necessitating post-treatment like chemical or combustion. Combustion proved more effective for continuous fiber composites. To streamline the process, direct combustion at 500 °C with varying hold times was tested, aiming to eliminate the need for a multi-step pyrolysis-combustion sequence. Clean fibers were obtained after 60 minutes. Increasing the temperature to 550 °C reduced the required hold time to 45 minutes for residue-free fibers. Recovered fibers were used to fabricate an 8-ply composite via vacuum-assisted resin transfer molding (VARTM), and tensile strength tests were conducted. The highest restoration tensile strength (26.81%) was achieved from a sample combusted at 500 °C for a 60-minute hold time. Notably, strength decreased with increased temperature and hold time. Complete residue removal without degrading fiber strength remains challenging, requiring further optimization of combustion parameters for better recycled GFRP fiber quality.

GRAPHICAL ABSTRACT (GA)



Innovative Valorization of Cigarette Butts: Pyrolysis-Derived Acetic Acid for Cost-Effective Salt-Free Deicer

Young-Min Kim[1,*], Byungcheol Lee[1], JeongHyun Kwon[1], Jihye Kwon[1], Juhye Kim[1]

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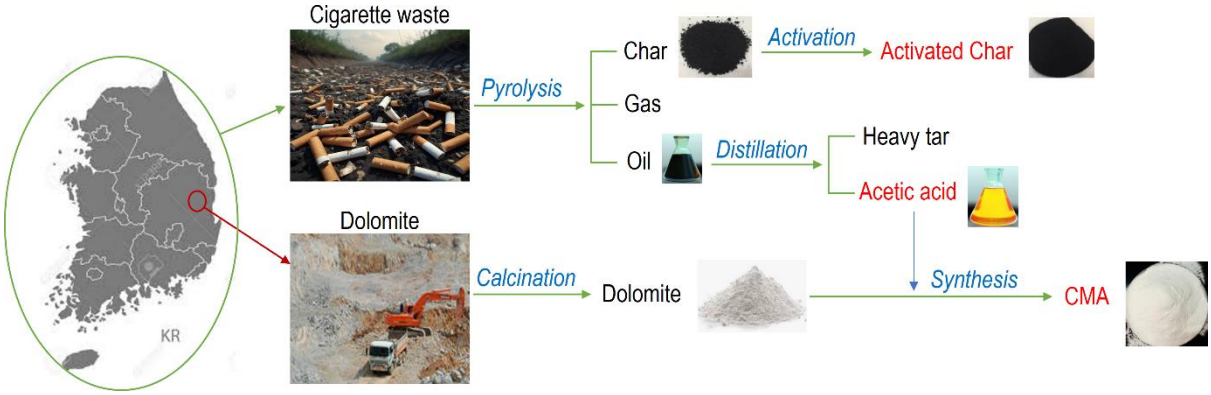
ABSTRACT

The environmental pollution caused by cigarette butt disposal and the use of high-salt deicing agents is not a problem confined to specific countries but a global issue. To address this, our research team conducted a study to produce large quantities of acetic acid through the pyrolysis of cigarette butts and use it as a raw material to synthesize salt-free deicing agents. After recovering contaminated filters from cigarette butts, we performed low-temperature pyrolysis at 400 °C and distilled the resulting oil to produce acetic acid. The distilled acetic acid was then synthesized with unused dolomite to produce calcium magnesium acetate (CMA). The synthesized CMA demonstrated ice-melting performance that was equal to or higher than that of calcium chloride, a common high-salt deicing agent. Additionally, the CMA synthesis process developed in this study is expected to be more cost-effective than conventional CMA production processes, as it utilizes waste materials.

GRAPHICAL ABSTRACT (GA)



Low-aromatic Oil Production Through Catalytic Pyrolysis of Waste Plastic-derived Wax

Hoesuk Yim[1], Soheil Valizadeh[1], Young-Min Kim[2], Kanghee Choi[3], Young-Kwon Park[1,*]

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[2]Department of Environmental Engineering, Daegu University, Republic of Korea
[3]Department of Chemistry and Chemical Engineering, Inha University, Republic of Korea

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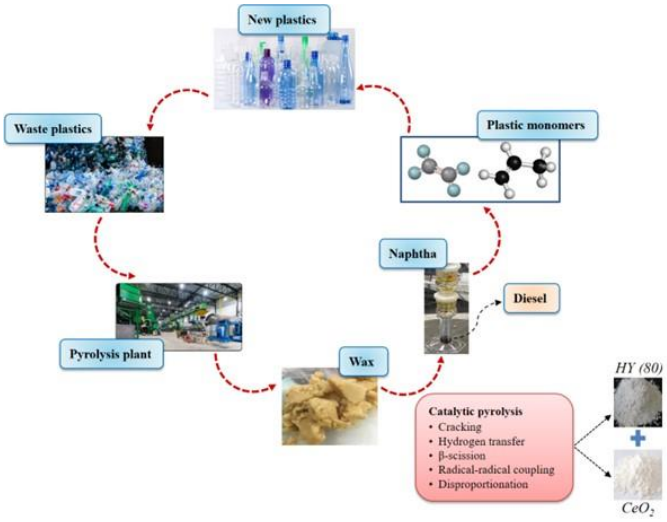
ABSTRACT

The chemical recycling of waste plastics into precursors for new plastics and diesel fuel offers a sustainable pathway towards a circular economy by reducing reliance on fossil energy sources. This study investigates the catalytic pyrolysis of pyrolytic wax (PW), obtained from waste plastics, aiming to produce low-aromatic hydrocarbons in the naphtha (C_5-C_{12}) and diesel (C_{13}-C_{22}) range. The catalytic performance of several commercial catalysts, including Al_2O_3, HZSM-5, and HY, along with mixed catalysts such as CaO/HY, MgO/HY, and CeO_2/HY, was evaluated to determine their effect on product distribution and wax conversion. Among the zeolites, HY exhibited superior performance, achieving high wax conversion and producing oils with low aromatic content, attributed to its moderate acidity and structural characteristics. Notably, mixed catalysts, particularly CeO_2/HY, enhanced diesel fraction yields while maintaining comparable naphtha production and wax conversion rates. This improvement is ascribed to the alkaline and redox properties of CeO_2, which reduced aromatic selectivity. The synergistic interaction between metal oxides and HY led to higher oil yields, with CeO_2/HY demonstrating optimal performance at a specific CeO_2 to HY ratio. These findings highlight the potential of using cost-effective metal oxides combined with zeolites as mixed catalysts in PW pyrolysis, offering a commercially feasible approach to low-aromatic oil production and effective PW management.

GRAPHICAL ABSTRACT (GA)



Sustainable Valorization of Polyurethane Packaging Foams Through Hydrothermal Liquefaction for Platform Chemicals Recovery

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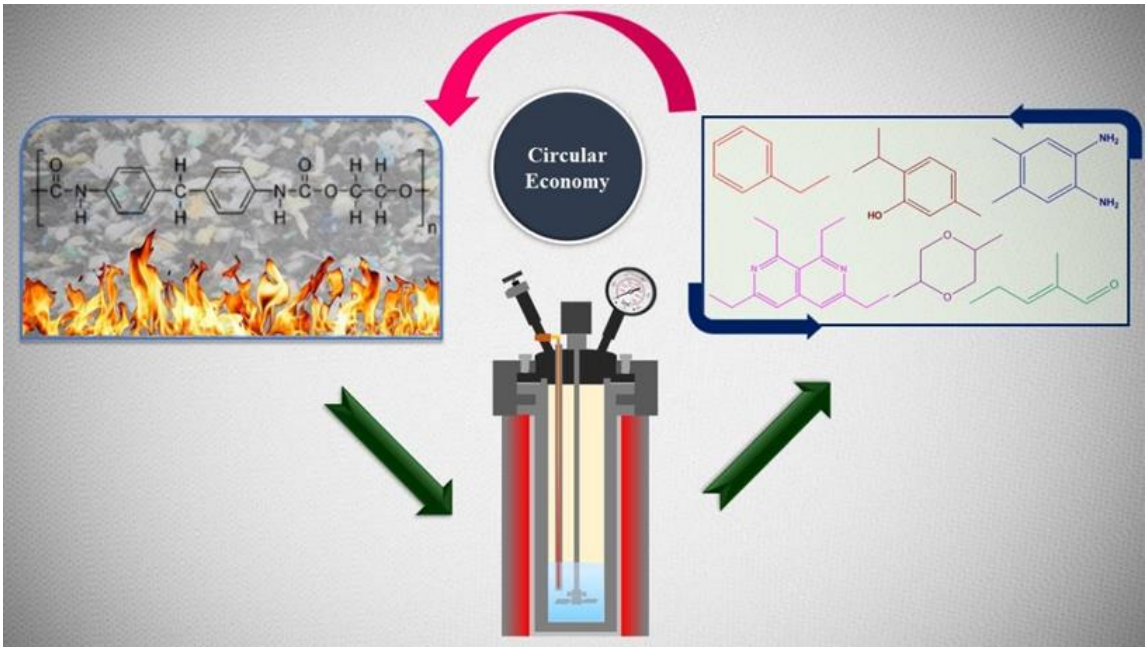
ABSTRACT

Polyurethane foam waste is a major contributor to global plastic waste, with an annual generation of 20 million tons worldwide. Its extensive use across industries such as construction, furniture, automotive, and packaging results in significant waste accumulation when these products reach the end of their life cycles. Hydrothermal Liquefaction is the sustainable approach for the recovery of platform chemicals from PU foams, supporting circular economy practices. In this study, a systematic HTL experiments were conducted on PU foam and the evaluation of product distribution and their quality by varying temperature (350–450 °C) with 10% solid loading and 30 min residence was also explored. The highest crude yield of 62 wt.% was obtained at 400 °C. Furthermore, the char yield decreased from 5.5 wt.% to 0.6 wt.%, while increasing the operating temperature from 350 °C–450 °C. Nitrogenates, aromatics and aromatic oxygenates were the overall major compounds identified in the crude phase using GCMS analysis. Denitrification of PU foams was effective at 350 °C compared to other two operating temperatures. Ethyl benzene (12–16 wt.%) is the common platform chemical selectively present in crude obtained from all experiments.

GRAPHICAL ABSTRACT (GA)



Production and Characterization of Biochar from Tender Coconut Waste

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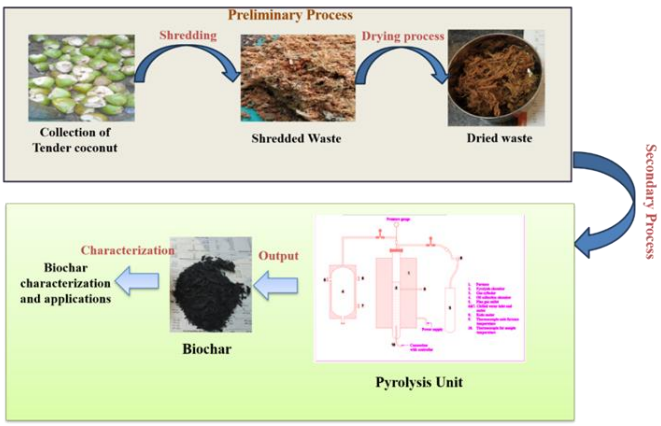
ABSTRACT

Solid Waste Management in developing countries including India has become very complicated due to mixed wastes generation from urban areas without segregation. It is very difficult to treat the mixed MSW which is collected and disposed in landfill or open dumps generating green house gases contributing to global warming. Mostly the organic fractions of municipal solid waste generated from many sources such as vegetable market, fish market, slaughter house etc are suitable for composting or bio-methanization. However, some of organic fractions of MSW especially wastes which are rich in fibrous like tender coconut is not suitable for bio-methanization and require special pre-treatment to disintegrate the fibre and lignocellulosic material. Hence, these waste require other suitable treatment methods like thermal process i.e, pyrolysis. In this investigation, the fibrous organic wastes generated from urban areas i.e., Tender Coconut (TC) is pyrolysed at 600 °C at residence time of 60 min and heating rate of 10 °C/min. A detailed characterisation of raw TC and biochar obtained from pyrolysis has been carried out. From this study, it is observed that about 50% weight of TC waste was reduced and remaining is obtained as biochar which ensures minimisation of carbon emission into the atmosphere. From biochar characteristics, it is evident that it is rich in carbon and micro nutrients which can be used for soil reclamation. Hence, the pyrolysis is a better disposal option for fibre rich solid waste like TC generated from the urban cities.

Keywords: Biochar; Fibrous organic waste; Pyrolysis

GRAPHICAL ABSTRACT (GA)



Development of A New Mill for Solids, Polymer and Inorganicmaterials

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ABSTRACT

This study presents the development and application of a new bench-top cryogenic mill (IQ MILL-2070) for the efficient milling of polymeric materials, crucial for accurate characterization by Pyrolysis-GC/MS (Py-GC/MS). Proper sample homogenization, particularly the reduction of particle size, is essential for obtaining reproducible pyrograms when analyzing polymers. Conventional cryogenic milling is often time-consuming, requires excessive liquid nitrogen, and produces high noise levels (~90 dB). The newly developed cryogenic mill addresses these issues by employing a patented high-speed up-and-down twisting motion for rapid, efficient milling with reduced noise levels (below 60 dB).

The mill was tested on 23 synthetic polymers under both cryogenic and room temperature conditions at 2,500-3,000 rpm, achieving particle sizes of less than 100 microns in 20 to 60 seconds, with milling yields exceeding 70%. These results demonstrate the mill's effectiveness in reducing sample particle size in a short time, improving the homogenization necessary for Py-GC/MS analysis.

To assess the effect of particle size on pyrogram reproducibility, polystyrene (PS) pellets were milled under various conditions, and
their pyrograms were compared to those obtained bya solution method, where PS dissolved in dichloromethane was injected into the sample cup.Pyrogram reproducibility, measured by the relativestandard deviation (RSD) of the peak area ratio of styrene trimer/styrene monomer (SSS/S), improved asthe particle size decreased. Milled PS samples exhibited RSD values below 3%, nearing the 0.9% RSD achieved by the solution method.

The study concludes that the newly developed IQ MILL-2070 offers significant advantages in milling efficiency, noise reduction, and pyrogram reproducibility. As particle size decreases, the reproducibility of Py-GC/MS analysis approaches that of solution-based methods, making the mill a valuable tool for polymer characterization.

Biochar-Enhanced Dark Fermentation for Sustainable Biohydrogen Production

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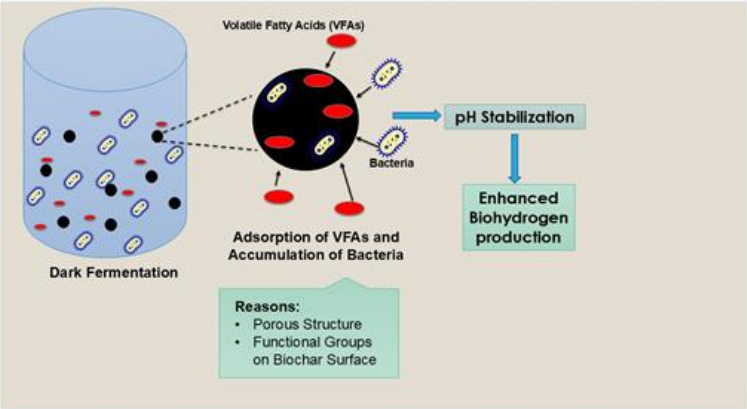
ABSTRACT

Biochar, a carbon-rich byproduct of biomass pyrolysis, has shown great potential in improving dark fermentation processes for biohydrogen production. Dark fermentation, which involves the anaerobic conversion of organic substrates into hydrogen, often suffers from low biohydrogen production of around 2.5 g/L due to microbial inhibition and substrate inefficiency. The incorporation of biochar addresses these challenges by providing a high surface area of around 950 m^2/g for microbial colonization, facilitating electron transfer, and enhancing microbial interactions. Biochar can adsorb inhibitory compounds such as volatile fatty acids and ammonia, preventing toxicity and stabilizing the pH within the optimal range (5.5–6.5). Studies report that biochar addition can increase hydrogen yield by 25–30% and reduce the accumulation of by-products like ethanol and lactic acid.

Moreover, functionalized biochar, such as metal-doped variants (e.g., Fe or Ni), has demonstrated catalytic effects, further enhancing substrate degradation and hydrogen generation. When paired with complex substrates like food waste, biochar has been shown to increase hydrogen production to 3.5 g/L. Biochar also mitigates hydrogen losses by suppressing methanogens and hydrogenotrophic microorganisms. Sustainable biochar derived from agricultural or algal residues offers environmental and economic advantages, supporting circular bio-economy models. Despite these promising results, challenges remain in optimizing biochar properties and scaling up the technology for industrial applications. This study presents an overview of biochar-enhanced dark fermentation, discussing key mechanisms, experimental results, and future directions to unlock its full potential for sustainable biohydrogen production.

GRAPHICAL ABSTRACT (GA)



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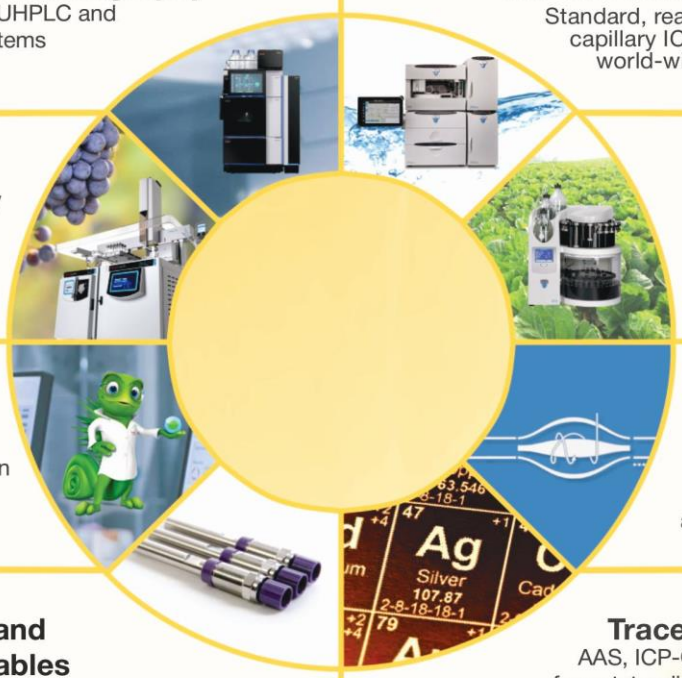

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Indian Institute of Technology Guwahati, the sixth member of the IIT fraternity, was established in 1994. The academic programme of IIT Guwahati commenced in 1995. At present the Institute has eleven departments, seven inter-disciplinary academic centres and five schools covering all the major engineering , science, healthcare, management and humanities disciplines, offering B.Tech., B.Des., M.A., M.Des., M.Tech., M.Sc., MBA and Ph.D. programmes. Within a short period of time, IIT Guwahati has been able to build up world class infrastructure for carrying out advanced research and has been equipped with state-of-the-art scientific and engineering instruments. Besides its laurels in teaching and research, IIT Guwahati has been able to fulfil the aspirations of people of the North East region to a great extent since its inception in 1994.

Indian Institute of Technology Guwahati's campus is on a sprawling 285 hectares plot of land on the north bank of the river Brahmaputra around 20 kms from the heart of the city. With the majestic Brahmaputra on one side, and with hills and vast open spaces on others, the campus provides an ideal setting for learning.

IIT Guwahati is the only academic institution in India that occupied a place among the top 100 world universities – under 50 years of age – ranked by the London-based Times Higher Education (THE) in the year 2014 and continues to maintain its superior position even today in various International Rankings. IIT Guwahati gained rank 32 globally in the 'Research Citations per Faculty' category and overall 364 rank in the QS World University Rankings 2024 released recently. IIT Guwahati has retained the 7th position among the best engineering institutions of the country in the 'India Rankings 2023' declared by the National Institutional Ranking Framework (NIRF) of the Union Ministry of Education. IIT Guwahati has been also ranked 2nd in the 'Swachhata Ranking' conducted by the Govt. of India. Also, IIT Guwahati ranks 6th globally in Sustainable Development Goal 7 (Affordable and clean energy) of the Times Higher Education Impact Rankings 2023.

Chair, PYROASIA 2024

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