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Declaration of Supervisor

I hereby declare that the work described in this thesis is the original work carried out by ***Mrs. Bidangshri Basumatary***, Research Scholar, Department of Chemistry, Bodoland University, Kokrajhar. As of now, we could publish four (04) papers in reputed international journals from the thesis which are original works of the scholar.

The published papers are described in the respective Chapters of the Thesis as shown below.

Publication	**Publisher**	**Chapter of Thesis**	**Scopus/ WoS**	**Impact Factor**
Waste *Musa paradisiaca* plant: An efficient heterogeneous base catalyst for fast production of biodiesel. *Journal of Cleaner Production*, **2021**;305:127089.	Elsevier	Chapter 2	Scopus & WoS indexed	11.1
Post-harvest waste to value-added materials: *Musa champa* plant as renewable and highly effective base catalyst for *Jatropha curcas* oil-based biodiesel production. *Bioresource Technology Reports*, **2023**;21:101338.	Elsevier	Chapter 3	Scopus indexed	-
Synthesis and characterization of heterogeneous catalyst from sugarcane bagasse: Production of jatropha seed oil methyl esters. *Current Research in Green and Sustainable Chemistry*, **2021**;4:100082.	Elsevier	Chapter 4	Scopus indexed	-
Catalytic efficacy, kinetics and thermodynamics studies of biodiesel synthesis using *Musa* AAA plant waste-based renewable catalyst. *International Journal of Energy Research*, **2024**;2024:8837343.	Wiley-Hindawi	Chapter 5	Scopus & WoS indexed	4.3

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Publication Declaration by the Candidate

I, **Bidangshri Basumatary,** do hereby declare that the following papers have been included in my thesis entitled "***Biodiesel production from non-edible oil via transesterification reaction using heterogeneous catalyst derived from post-harvest plants***."

It is my affirmation that all of the papers listed are my original work or have been properly cited and referenced. I acknowledge that these papers have contributed to the research presented in my thesis.

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ABSTRACT

Biodiesel production from non-edible oil via transesterification reaction using heterogeneous catalyst derived from post-harvest plants

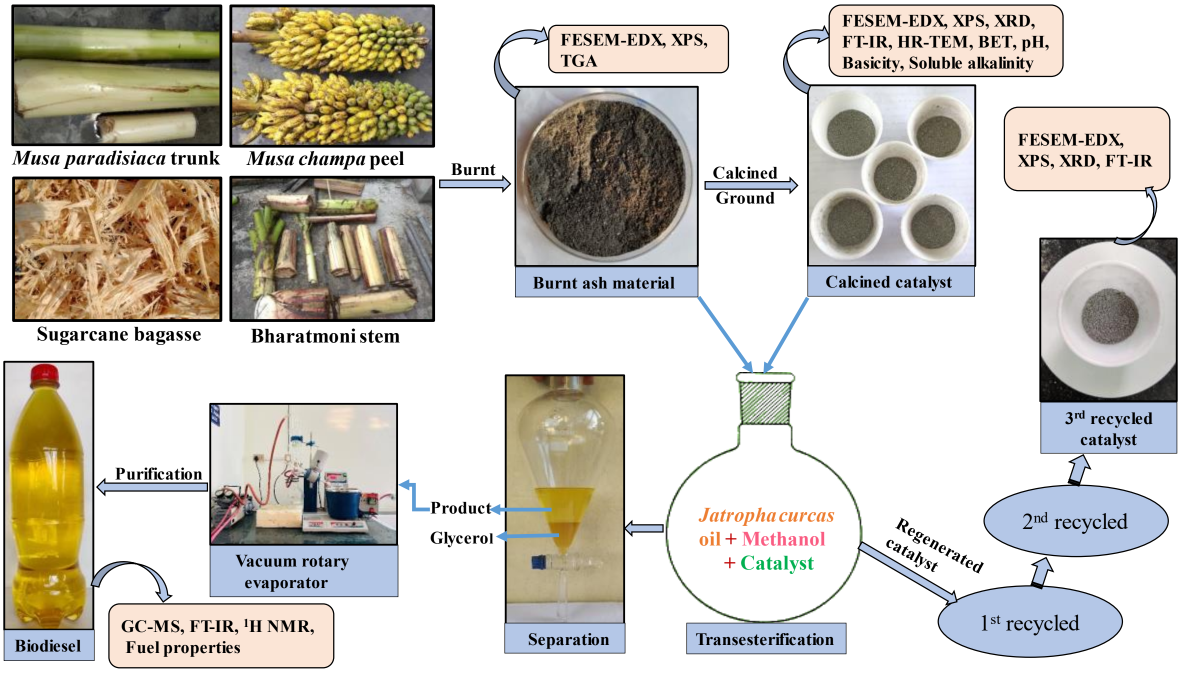

Fig. 1. Graphical abstract representing the works performed in the thesis.

It is a fact that fossil fuels are non-renewable resources, and their depletion will exhaust their reserves in the future. As long as their reserves are continuously used, the energy crisis will worsen. The combustion of fossil fuels has been adversely affecting the environment. As a solution to reduce environmental constraints and meet the energy crisis, biodiesel has been developed as a renewable energy. Fuels made from renewable resources, such as biodiesel, have many advantages over fossil fuels. In this context, the current research focuses on investigating the application of post-harvest material as a catalyst in the production of biodiesel.

Chapter 1 of this thesis discusses the energy demand and crises, environmental concerns, the evolution of biodiesel and its origins. Several sources of oil feedstock, transesterification processes, relevant heterogeneous base catalysts, and the synthesis of catalysts from agro-waste are briefly discussed in this chapter. The performance of several catalysts reported by various authors has been addressed. **Chapter 1** also discusses the analysis of fuel qualities and comparison within the standard limits. The scope of the current study, including the aims and objectives of this research work is mentioned at the end of this chapter.

In this thesis, **Chapter 2** showed the investigation of the heterogeneous base catalysts derived from the peel, trunk and rhizome of *Musa paradisiaca* (Malbhog). The catalysts were investigated for biodiesel production using *Jatropha curcas* oil. Catalysts were characterized using powder XRD, FT-IR, BET, EDX, FESEM, XPS and HRTEM. EDX and XPS studies exhibited that *M. paradisiaca* trunk catalyst possessed higher potassium content than the peel and rhizome catalysts. *M. paradisiaca* trunk catalyst showed better efficacy which yielded 97.65 % of biodiesel at 65 ºC in 9 min of reaction time using 5 wt. % of catalyst and 9:1 MTOMR (methanol to oil molar ratio). Activation energies using *M. paradisiaca* peel, trunk and rhizome catalysts were found to be 48.68, 47.56 and 48.93 kJ mol^{-1}. The catalyst was successfully reused up to the 3rd reaction cycle with 91.23 % of biodiesel yield. Biodiesel was characterized using FT-IR, ^{1}H NMR, ^{13}C NMR and GC-MS. Biodiesel properties and its (Na + K) and (Ca + Mg) concentrations were found to be within the limit of ASTM D6751 and EN 14214 standards.

In Chapter 3, catalysts were prepared from the post-harvest stem, rhizome and fruit peel of *Musa champa* plant and applied in biodiesel production from *Jatropha curcas* oil. The calcined *M. champa* peel (CMCP-550) catalyst contained the highest amount of K (47.49 wt. %) and exhibited the highest basicity of 1.25 mmol g^{-1}, which in turn showed the best efficacy for the reaction in comparison to other prepared catalysts of this work. The CMCP-550 catalyst with a surface area of 6.848 m^2 g^{-1} could produce a maximum biodiesel yield of 98.27 % at the optimum reaction conditions (ORCs) of 9:1 MTOMR and 5 wt. % of catalyst loaded at 65 ºC in 10 min. The CMCP-550 catalyzed reaction exhibited a good activation energy of 54.256 kJ mol^{-1} with a turnover frequency (TOF) of 14.15 h^{-1}.

Chapter 4 includes the preparation of a solid catalyst that has been derived by calcination (550 ºC, 2 h) of waste sugarcane bagasse ash and applied for the production of biodiesel from jatropha oil. The prepared catalyst was well-characterized by the BET method, FT-IR, XRD, FESEM, EDX, HRTEM and XPS. The analysis revealed that the catalyst is composed of various metal oxides and carbonates. The catalyst could produce 92.84 wt. % yield of biodiesel at 9:1 MTOMR, 10 wt. % of catalyst and at 65 ºC in 285 min, and found to be reusable. The polycrystalline catalyst with a surface area of 7.66 m^2 g^{-1} and basic strength within $10.1 < H\_ < 18.4$ possesses good efficacy for the reaction with a turnover frequency (TOF) of 6.59 h^{-1}. The kinetic and thermodynamic parameters of the reaction were studied.

Chapter 5 also represented the study on the synthesis of an eco-compatible, inexpensive, and effective catalyst from the *Musa* AAA plant for the production of biodiesel using jatropha oil. The burnt ashes obtained from the fruit peel, stem, and rhizome of *Musa* AAA plant were calcined at 550 ºC for 2 h, characterized employing sophisticated techniques, and catalytic activities were tested. Utilization of the CBS-550 catalyst achieved a higher biodiesel yield of 96.97 % in a minimum time of 12 min compared to CBP-550 and CBR-550 catalysts under ORCs of 9:1 MTOMR, 5 wt. % of catalyst loaded at 65 ºC. The surface morphology of the prepared catalysts (CBP-550, CBS-550, and CBR-550) revealed mesoporous material. The kinetics and thermodynamics studies of the reactions catalyzed by the present catalysts follow the pseudo-first order kinetic model exhibiting a non-spontaneous and endothermic pathway. The reaction catalyzed by the CBS-550 catalyst showed the lowest activation energy of 44.36 kJ mol^{-1} and is known to be the superior catalyst among the derived catalysts of this work.

Chapter 6 summarizes the current research and provides conclusions. An overview of elemental composition, BET surface area, pore diameter, pore volume as well as pH values, basicity values, and soluble alkalinity are presented in this chapter. The performances of catalysts developed in this work and their catalytic activities and reusability under ORCs are presented.

The current study demonstrated the successful production of biodiesel through transesterification reactions using the catalysts developed from *Musa paradisiaca*, *Musa champa*, sugarcane bagasse, and Bharatmoni banana (*Musa* AAA). This study has proven that a heterogeneous base catalyst prepared from a post-harvest banana plant possesses high catalytic activity because of rich potassium as its chief constituent, which is present in the form of carbonates and oxides. The investigated catalysts of the present study are significantly beneficial because they are cheap material, abundant, easy to prepare, renewable and eco-friendly.

List of Publications

Publications from Thesis

1. **Basumatary B**, Basumatary S, Das B, Nath B**,** Kalita P. Waste *Musa paradisiaca* plant: An efficient heterogeneous base catalyst for fast production of biodiesel. *Journal of Cleaner Production*, **2021**;305:127089 (Elsevier, Impact Factor = 11.1).
2. **Basumatary B**, Das B, Nath B, Basumatary S. Synthesis and characterization of heterogeneous catalyst from sugarcane bagasse: Production of jatropha seed oil methyl esters. *Current Research in Green and Sustainable Chemistry*, **2021**;4:100082 (Elsevier).
3. **Basumatary B**, Brahma S, Nath B, Basumatary SF, Das B, Basumatary S. Post-harvest waste to value-added materials: *Musa champa* plant as renewable and highly effective base catalyst for *Jatropha curcas* oil-based biodiesel production. *Bioresource Technology Reports*, **2023**;21:101338 (Elsevier).
4. **Basumatary B**, Atmanli A, Azam M, Basumatary SF, Brahma S, Das B, Brahma S, Rokhum SL, Min K, Selvaraj M, Basumatary S. Catalytic Efficacy, Kinetic, and Thermodynamic Studies of Biodiesel Synthesis Using *Musa AAA* Plant Waste-Based Renewable Catalyst. *International Journal of Energy Research*, **2024**;2024:8837343 (Wiley & Hindawi, Impact Factor = 4.3).

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1. **Basumatary B**, Nath B**,** Kalita P, Das B, Basumatary S. Yellow oleander (*Thevetia peruviana*) seed as a potential bioresource for industrial applications. *Mini-Reviews in Organic Chemistry*, **2020**;17(7):855-871 (Bentham Science Publisher, Impact Factor = 2.3).
2. Basumatary S, Nath B, Das B, Kalita P, **Basumatary B**. Utilization of renewable and sustainable basic heterogeneous catalyst from *Heteropanax fragrans* (Kesseru) for effective synthesis of biodiesel from *Jatropha curcas* oil. *Fuel*, **2021;**286:119357 (Elsevier, Impact Factor = 7.4).
3. Brahma S, Nath B, **Basumatary B**, Das B, Saikia P, Patir K, Basumatary S. Biodiesel production from mixed oils: A sustainable approach towards industrial biofuel production. *Chemical Engineering Journal Advances*, **2022;**100284 (Elsevier, Impact Factor = 5.5).

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5. Nath B**, Basumatary B**, Brahma S, Das B, Kalita P, Rokhum SL, Basumatary S. *Musa champa* peduncle waste-derived efficient catalyst: Studies of biodiesel synthesis, reaction kinetics and thermodynamics. *Energy*, **2023**;270:126976 (Elsevier, Impact Factor = 9.0).
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8. Basumatary SF, Das B, Das BK, Hoque M, Brahma S, **Basumatary B**, Patir K, Selvaraj M, Rokhum SL, Basumatary S. Recent advances in magnetic solid catalysts: Synthesis, stabilization and application in cleaner production of biodiesel, *Energy Nexus*, 2024, 100318 (Elsevier, Impact Factor = 8.0).
9. Kalita P, **Basumatary B**, Saikia P, Das B, Basumatary S. Biodiesel as renewable biofuel produced via enzyme-based catalyzed transesterification. *Energy Nexus*, **2022**, 6, 100087 (Elsevier, Impact Factor = 8.0).
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11. **Basumatary B**, Nath B, Basumatary S. Homogeneous catalysts used in biodiesel production. *Title of Book*: Biodiesel Production: Feedstocks, Catalysts and Technologies**.** ISBN: 9781119771364**.** John Wiley & Sons Ltd. **2022,** https://doi.org/10.1002/9781119771364.ch5.
12. Brahma S, Basumatary SF, **Basumatary B**, Newar UD, Basumatary S. Production of biodiesel from soybean oil. *Title of Book*: The Production of Biodiesel and Related Fuel Additives. ISBN: 978-981-5196-75-7. Bentham Science, 2024, DOI: 10.2174/9789815196740124060004.

Paper Presentations in Conference/Seminar

1. **Basumatary B,** Kalita P, Das B, Basumatary S. Banana Plant Derived Materials as Heterogeneous Catalyst for Biodiesel Synthesis. National Seminar on Frontiers of Chemical Sciences, 25-26th of August, **2019**, Kokrajhar Govt. College, Kokrajhar, Assam, India.
2. Nath B, **Basumatary B**, Kalita P, Basumatary S. Investigation of Heterogeneous Base Catalyst Derived from Agro-Waste for Biodiesel Production. National Conference on Green, Sustainable and Evolving Sciences (**GSES-2019**), 28th-29th of June, 2019 at Cotton University, Guwahati, Assam, India.
3. **Basumatary B,** Kalita P, Das B, Basumatary S. Heterogeneous Catalyst Derived from *Musa paradisiaca* for Effective Synthesis of Biodiesel. International Conference on Future Aspects of Sustainable Technologies (**FAST 2019**), 11-12th of November, 2019 at Central Institute of Technology, Kokrajhar, Assam, India.
4. **Basumatary B,** Kalita P, Das B, Basumatary S. Biodiesel production from jatropha oil via transesterification reaction using a solid base catalyst from banana plant. International Conference on Future Aspects of Sustainable Technologies (**FAST 2020**), 20-21th of October, 2020 at Central Institute of Technology, Kokrajhar, Assam, India.
5. **Basumatary B**, Basumatary S. Application of an eco-friendly heterogeneous catalyst derived from *Musa champa* in conversion of jatropha oil to biodiesel. National Conference on Advances in Sustainable Chemistry and Material Science (**ASCMS-2022**), 29-30th of April, 2022 at Department of Chemistry, Bodoland University, Kokrajhar.
6. **Basumatary B**, Basumatary S. Utilization of an agro-waste and higly efficient heterogeneous catalyst for conversion of *Jatropha curcas* oil into biodiesel. National Conference on Science & Technology for Sustainable Development (**STSD-2022**), 9th-10th of September, 2022 at Science College, Kokrajhar.
7. **Basumatary B**, Basumatary S. Exploration of an agro-waste material as a heterogeneous base catalyst for biodiesel synthesis from *Jatropha curcas* oil. International Symposium on Emerging Trends in Chemical Sciences (**ETCS-2023**), 2nd-4th of March, 2023 at North Eastern Hill University, Shillong, Meghalaya, India.
8. **Basumatary B**, Basumatary S. Utilization of an agro-waste based heterogeneous catalyst in conversion of *Jatropha curcas* oil to Biodiesel. Bodoland International Knowledge Festival **2023**, India, 27th-2nd of March, 2023 at Bodoland University, Kokrajhar, India.