ABSTRACT

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

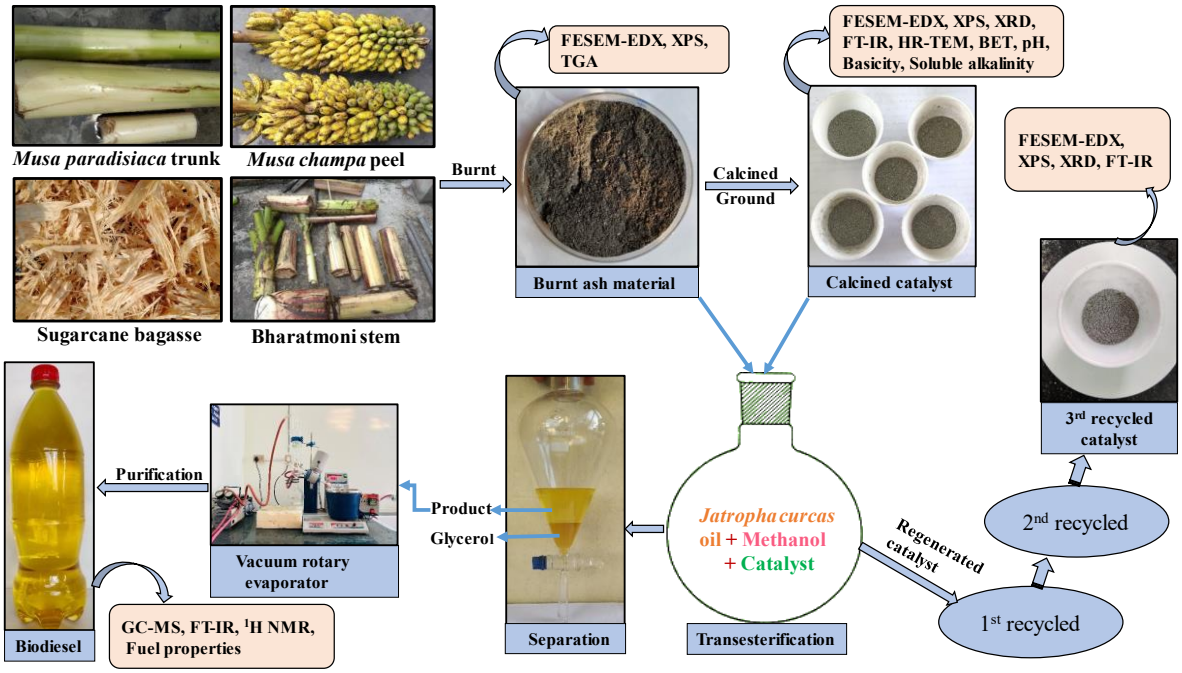

Fig. 1. Graphical abstract representing the works performed in the thesis.

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.