ABSTRACT

Utilization of Waste Plant Derived Materials as Heterogeneous Base Catalyst for Biodiesel Synthesis

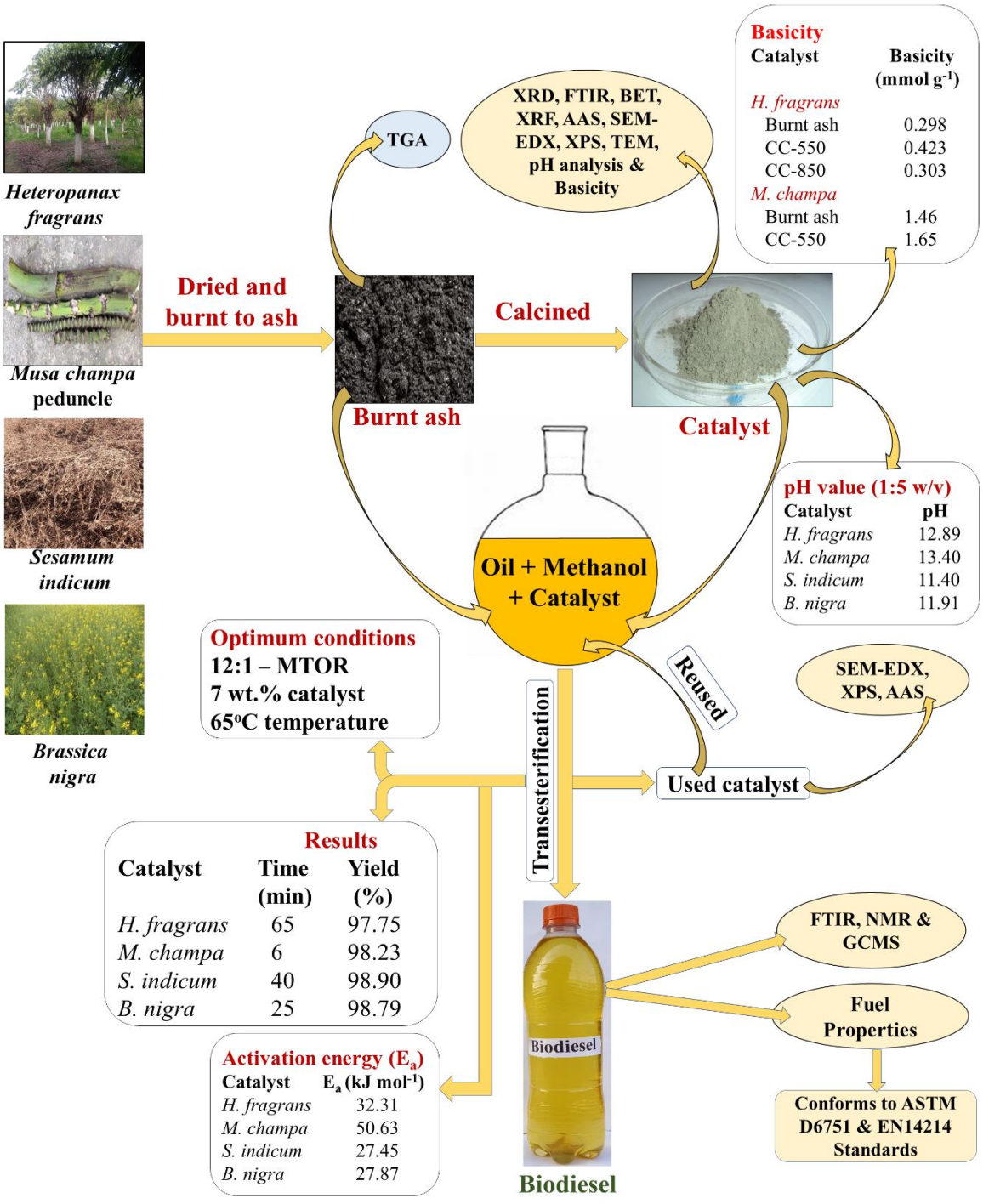

Fig. 1. Graphical abstract depicting the works done in the Thesis.

Global energy demand is surprisingly increasing due to intense growth in population, transportation and industrialization. To combat with the present dwindling situation of fossil fuel sources and environmental worries, emphasis on the development of alternative renewable and environmentally benign energy sources for utilization is being intensified from the last two decades. In this regard, biodiesel prepared from various renewable natural resources is gaining global attention as an environmentally friendly and sustainable alternative since it is biodegradable, non-toxic, carbon-neutral, and renewable. Biodiesel is conveniently synthesised by transesterification of vegetable oil with methanol in presence of a catalyst. Heterogeneous base catalysts derived from waste materials due to their numerous advantages over homogeneous and enzyme catalysts are attracting the scientific community. Waste plant derived heterogeneous catalysts are preferred over chemical sources and CaO based natural derived heterogeneous catalysts. In recent years, a number of heterogeneous catalysts derived from waste plant sources are reported. There is still a need to extensively search of the superior catalyst which is not only cost-free and low-cost but should also be easily available and eco-friendly that can be served for large scale application in a cost-effective and eco-friendly production of biodiesel. Therefore, in this Thesis, we have reported the development of excellent solid catalysts from four different waste plants for biodiesel synthesis.

In this study, **Chapter 1** of the Thesis gives the overview of biodiesel including importance of biodiesel, catalyst used in the preparation of biodiesel, review of published literatures of the agro-waste based catalysts used in biodiesel synthesis and fuel properties of reported biodiesels. At the end of the chapter, objectives of the present study were also incorporated.

Chapter 2 includes the catalytic activity study of waste *Heteropanax fragrans* (Kesseru) derived catalyst in biodiesel synthesis from *Jatropha curcas* oil. The catalyst preparation was done by burning the dry waste into ash followed by calcination. The detail characterization of the catalyst was done by employing powder X-ray diffractometer (PXRD), Brunauer-Emmett-Teller (BET), Fourier transform infrared (FT-IR) spectrometer, Field emission scanning electron microscope (FESEM), Energy dispersive X-ray (EDX), X-ray photoelectron spectrometer (XPS) and High-resolution transmission electron microscope (HRTEM) techniques including the determination of pH and basicity. The optimum reaction conditions (ORCs) such as methanol to oil ratio, catalyst loading and reaction temperature were examined. The reusability study was also carried out under ORCs. The produced biodiesel was characterized by FT-IR, NMR and GC-MS techniques. Fuel properties of the produced biodiesel were found within the limit of international standards prescribed by ASTM D6751 and EN14214.

Chapter 3 describes waste *Musa champa* peduncle as heterogeneous catalyst source in biodiesel production. The catalyst preparation was also done by burning the dry waste followed by calcination. The characterization of the catalyst was performed by sophisticated analytical techniques. *Jatropha curcas* oil was the feedstock for biodiesel synthesis. Determination of turnover frequency, kinetics and thermodynamic studies of the transesterification and reusability were carried out in the chapter. The characterization of biodiesel and fuel property analyses were also performed.

Chapter 4 depicts *Sesamum indicum* derived catalyst in biodiesel synthesis from sunflower oil as biodiesel feedstock. Catalyst preparation involves burning and calcination. Similar characterization techniques as mentioned in previous chapters along with TGA and AAS analyses were also performed. The produced biodiesel was characterized similarly with FT-IR, NMR and GC-MS techniques as previous chapters. The fuel properties of the biodiesel are determined and found to meet the limits of international standards.

Chapter 5 demonstrates waste *Brassica nigra* derived catalyst in biodiesel production. Catalyst preparation and characterization involve similar methods. Soybean oil, *Jatropha curcas* oil and *Thevetia peruviana* oil were investigated as biodiesel feedstocks. Under ORCs, all the biodiesel feedstocks were examined using the prepared catalyst and showed excellent biodiesel yield, and the catalyst displayed good reusability character.

Chapter 6 gives the brief summary of the present study as well as conclusion drawn out of it. Comparative analysis of the catalysts was undertaken and described briefly. Comparison of elemental composition, surface area, pH, and basicity values are summarized in this chapter. Catalytic efficiency in biodiesel production at ORCs are summarized along with the reusability potential. Comparative analysis of fuel properties was also depicted in the chapter. Probable future work to be performed in the area is also proposed at the end of the chapter.

The present study successfully developed four different heterogeneous base catalyst from *H. fragrans*, *M. champa* peduncle, *S. indicum* and *B. nigra* wastes. Catalyst preparation involves drying of waste plants followed by burning to ash and calcination. Both the burnt ash and calcined materials were investigated as catalyst in biodiesel synthesis from different oil feedstocks. XRD and FT-IR analyses depicted the presence of oxides and carbonates of alkali and alkaline earth metals in the prepared catalysts. EDX and XPS techniques confirmed the presence of higher percentage of potassium compared to other metals, which is acting as the main active component in the catalysis of biodiesel synthesis. Higher potassium content in the catalyst resulted in higher pH value, high basicity and subsequently higher catalytic activity.

The raw materials for the preparation of the catalysts in this study are readily available, and the cost of catalyst depends mainly on the energy spent for their production which may be considered very nominal. Thus, the catalysts developed have the advantages for reducing the production cost of biodiesel. Since the catalysts were derived from biodegradable raw materials, these are non-corrosive, easy to handle, and green catalysts. Besides, large scale disposal of these catalysts after use would not produce any potential harm to the environment and society as well. Moreover, utilization of these wastes in a convenient way to the benefit of mankind as a part of waste management is highly encouraged and thus the present catalysts which are highly efficient green catalyst can be recommended as a potential candidate for biodiesel production at industrial scale in a cost-effective manner.