Pyrolysis behaviour of low value biomass towards renewable fuel and valuable chemicals

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by

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Chapter-7

Conclusion and Suggestions for Future Work

7. Suggestions

This chapter summarizes the important observations presented in this thesis and gives brief incitement of the scope of future research to be carried out.

7.1 Conclusion

The need for alternative, less polluting, and sustainable energy sources is being driven by rising environmental pollution, related global issues like climate change and global warming, as well as the price and limited supply of fossil fuels, which are primarily found in politically unstable parts of the world. Agricultural leftovers, municipal solid waste, and industrial wastes are all being investigated as almost carbon-neutral and sustainable renewable energy supplies. Among these, lignocellulosic biomass derived from diverse sources is being investigated as a potential replacement for traditional fossil fuels. On various counts, their worldwide availability and renewable nature make them more appealing than other renewable energy sources. As a result, global efforts are being undertaken to utilize them as feedstock for the production of cleaner fuels and other value-added products via biochemical and/or thermochemical conversion methods. For a country like India, the potential is huge yet remains untapped. In this thesis, three low-value biomass such as *Lagerstroemia speciosa* seed hull (LS), mustard straw (MS), and *Sesbania bispinosa* (SB), were selected as potential candidates for pyrolysis. The physicochemical study of these three biomasses revealed their huge bioenergy potential. The thermogravimetric analyses of the biomasses studied in this work showed more or less similar profiles but exhibited a difference in the degradation temperature range and residual mass values. The degradation profile of all biomasses showed that the maximum weight loss was observed between the temperature range of 200 – 650 °C. The findings show that each kind of biomass has a unique breakdown rate determined by its cellulose, hemicellulose, and lignin composition.

The pyrolysis behavior and kinetic parameter estimation of LS biomass were executed in a thermogravimetric analyzer. The physicochemical examination of LS biomass showed great potential for bioenergy feedstock. Thermal stability analysis of biomass at dynamic heating rates verified that when heating rates increased, the degradation peak moved to a higher location without affecting degradation performance. The kinetic study demonstrated that the results of the pyrolysis experiment are consistent with the experimental data. The change in enthalpy, Gibb's free energy, and entropy indicated the type of the reaction, energy provided by the components, and reactivity of the system, respectively. The thermal pyrolysis of LS was performed in a laboratory-based semi-batch reactor. The RSM based on CCD was employed to optimize pyrolysis process factors to maximize the bio-oil yield. The results revealed that the optimum condition for the maximum bio-oil yield (45.6%) was: temperature = 550°C, heating rate = 65°C/min, and flow rate of inert gas (N_2) = 60ml/min; however, at this condition, the predicted bio-oil yield using RSM was 44.98%. ANOVA results revealed that the influence of temperature was more significant than heating rate and N_2 flow.

The thermal degradation behavior and optimization of pyrolysis process variables of MS biomass were investigated. The kinetic result suggested that pyrolysis followed a complex reaction mechanism, and with an upsurge in heating rate, TG thermograph shifted to the upper-temperature province without affecting the degradation pattern. The ANOVA technique confirmed that temperature affected the bio-oil yield more than the gas flow and heating rates. The highest bio-oil yield of 44.69% was found at optimum operating conditions. The results showed that the MS biomass could be a very good feedstock for recovering energy and value-added products through the thermal conversion route.

The thermal degradation behavior and optimization of pyrolysis process variables of SB biomass were investigated. The physicochemical characterization results revealed tremendous bioenergy potential of SB with high carbon and volatile matter content. The thermogravimetric results revealed that major mass loss was found in the temperature range of 220 to 650°C, showing the optimal temperature range for the pyrolysis process. The kinetic analysis results revealed that the apparent activation energy altered as the conversion progressed, indicating the complex and multistep process. The thermodynamic study revealed that the difference between E and ΔH is close to (~5 kJ/mol), implying that product formation can be accomplished by supplying very low supplemental energy. The master plot methodology was used in combination with the Criado method to estimate the reaction mechanism, which revealed a complex reaction mechanism with progressive conversion. ANOVA results revealed that temperature had a more promising impact on bio-oil yield than heating rate and N_2 flow rate. The optimum parameters (temperature = 585°C, heating rate = 60°C/min, and N_2 flow rate = 125 ml/min) for the highest bio-oil yield of 42.53 %. The characterization of the biochar revealed its applicability in multipurpose applications. The findings confirmed that SB biomass can be used as a substitute for conventional fuel through pyrolysis.

7.2 Suggestions for Future Work

Based on the present investigation, there is further scope for investigation to enhance science and technology.

1. Development and scale-up of new pyrolyzer for production of higher liquid yield.
2. Developing a new mathematical model to investigate the pyrolysis characteristics of biomass by using thermogravimetric analysis produces minimum or negligible error.
3. Bio-oil can be further upgraded by catalytic cracking, hydrodeoxygenation, and catalytic hydrotreating to enhance its fuel characteristics and use as an alternative to conventional fuel.
4. Various useful chemicals such as acids and some hydrocarbons are extracted from the aqueous fraction of pyrolytic liquid.

5. Catalytic pyrolysis of these biomasses and other waste biomasses into valued-added products.
6. Pilot plant study of these selected biomasses.
7. Co-pyrolysis of these biomasses with plastic waste to enhance the quality of bio-oil.