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## CHAPTER 6

### Overall conclusions and future recommendations

Based on the present study, important conclusions and recommendations for future studies can be summarized as follows:

#### 6.1 Main conclusions of this study

- High volatile matter, high HHV, low ash and moisture content inferred the suitability of *Melia azedarach* sawdust for pyrolysis.
- TGA findings revealed that thermal degradation of MAS took place in three stages related to elimination of moisture, followed by decomposition of hemicellulose, cellulose and finally lignin decomposition. Maximum devolatilization occurred in the temperature range of 200 - 480 °C.
- Average activation energy calculated from KAS, FWO and Starink models were 161.18, 162.68 and 161.41 kJ/mol, respectively.
- Low value of activation energy indicates requirement of less energy for carrying out pyrolysis. It also signifies easy thermal decomposition of the biomass.
- Among all parameters (temperature, N<sub>2</sub> flow rate, bed height, particle size, heating rate and pyrolysis time) temperature showed the pronounced effect on product yield distribution of pyrolysis.
- Maximum bio-oil yield was obtained at 550 °C temperature, 150 mL/min nitrogen flow rate, 8.4 cm bed height and particle size in the range of 0.18–0.29 mm at a

heating rate of 20 °C/min coupled with 60 min pyrolysis time. Bio-oil yield was 50.6 wt.%, and bio-char and gas yield were 24.4 and 24.9 wt.%, respectively.

- These values of operating parameters provided adequate heat and mass transfer for breakdown of MAS into condensable volatile hydrocarbon compounds inhibiting over breakdown of MAS into gaseous products.
- In bio-oil aliphatic, olefinic and aromatic compounds like alcohol, ketone, alkyl, and aryl were confirmed by FTIR, NMR and GC–MS analysis, indicating its potential as a valuable chemical feedstock.
- Proximate and ultimate analysis showed increase in carbon content of bio-char. So, it can be used for carbon sequestration in the soil. The HHV of biochar increased as compared to biomass.
- Improvement in mass loss rate and reduction in the temperature of biomass thermal degradation was attained due to catalytic effects on addition of Cu catalyst.
- Cu catalyst facilitated better heat transfer within the biomass. This could mainly be attributed to the ability of metal catalyst to enhance the rate of cracking and reforming reactions.
- Cu acted as a catalyst and decreased temperature requirement for degradation of catalytic *Melia azedarach* sawdust (maximum bio-oil yield was obtained at 500 °C for catalytic pyrolysis of *Melia azedarach* sawdust while that for non-catalytic pyrolysis of *Melia azedarach* sawdust was obtained at 550 °C) and also enhanced rate of reaction as compared to that of non-catalytic *Melia azedarach* sawdust.

- Bio-oil properties were analysed by FTIR, NMR and GC-MS analysis which indicated presence of phenols, aldehydes and ketones etc. SEM analysis revealed the porous nature of bio-char.
- Cu imparted its catalytic effects and reduced the oxygen content of the bio-oil along with enrichment in hydrocarbons and phenolic content in catalytic bio-oil.
- This study demonstrated possibility of reducing secondary environmental pollution and provides a low-cost and sustainable solution for using heavy metal (Cu) and *Melia azedarach* sawdust for energy generation.

## 6.2 Recommendations for future studies

Based on the present study certain recommendations for future works are summarized as follows:

- Co-pyrolysis of *Melia azedarach* sawdust with other feedstocks like waste lignocellulosic biomass, plastic or municipal solid waste.
- Study of statistical optimization using Response Surface Methodology (RSM).
- Development of other metallic or bi-metallic catalysts for *Melia azedarach* sawdust pyrolysis.
- Exploration of more abundantly available waste materials which could yield robust results by serving as a catalyst for pyrolysis.
- Apart from using fixed bed reactor like in the present work, other reactor types should also be studied.
- Some pre-treatments like torrefaction before performing non-catalytic and catalytic pyrolysis.
- Using bio-char for preparation of materials like catalysts, adsorbents, capacitors, chemical reagents, soil additives, and other value-added products.
- Identifying and overcoming technical, economical, and social challenges associated with the practical and commercial scale application of pyrolysis process.