Abstract

The most available non-edible seeds in India such as Mahua (*Madhuca indica*), Karanja (*Pongamia pinnata*) and Niger (*Hyoscyamus Niger L.*) were selected as the feedstock for the production of bio-oil through thermo-chemical conversion method of pyrolysis. Prior to pyrolysis the feed materials were characterized to study their suitability and then processed to maximize the yield and quality of bio-oil. Various characterization techniques were followed, such as proximate analysis, ultimate analysis, extractives and composition analysis, crystallinity index, FTIR analysis and TG analysis. The characterization study concluded that the chosen feedstocks were rich in extractives and cellulose contents and least in lignin and hemicelluloses contents. This information predicted that pyrolysis of such feedstocks may produce higher yield of liquid product. The thermal analysis confirmed that the decomposition temperature for all of the seed materials lied in the temperature range of 150-450 °C. The kinetic study for all the feed materials were studied and compared by varying the rate of heating from 5 to 15 °C min^{-1} using TGA/DTG and DSC analysis. The study illustrated that the seeds had very close activation energy among them. The comparison of kinetic parameters related to heating rate concluded that heating rate had a direct affinity towards activation energy and pre-exponential factor. Higher heating rate causes faster decomposition with a short vapor residence time. From DSC analysis, it was clear that the evolution of moisture resulted in exothermic peak whereas hemicelluloses, cellulose and lignin provided the endothermic peak. On the basis of TGA study, thermal pyrolysis was performed at heating rate of 25 °C min^{-1} in between 500 °C and 600 °C, which concluded that 525 °C was the optimum temperature for Mahua seed and 550 °C for Karanja and Niger seed respectively. It was noticed that the pyrolytic liquid was separated into organic phase and aqueous phase as top and bottom product. The organic liquid was characterized for their fuel properties and compositions which confirmed that all the seed pyrolytic oils had very close calorific value to that of diesel. However, the thermal pyrolytic oils were highly viscous and acidic in nature and lost their flow ability below 15 °C. To enhance the fuel properties catalytic pyrolysis was carried out at the optimum temperature using CaO, Al_2O_3 and Kaolin as catalyst at various feed to catalytic ratio. The observed result concluded that the catalytic activity varies with the feed types; however, the yield of pyrolytic oil was more or less similar to that of thermal pyrolytic yield. The yield was more at lower feed to catalyst ratio (8:1). Nevertheless, it enhanced the calorific value, reduced the viscosity, and altered the pH of the pyrolytic oil from acidic to basic in comparison with thermal pyrolytic oil. The influence of waste polystyrene in feed during pyrolysis was studied at lower to higher ratio. The results confirmed that the conversion of seed increased by the addition of waste polystyrene. However, at 1:1 seed to polystyrene ratio resulted in lower heating value pyrolytic oil compared to 2:1 ratio, since the increase in the amount of aromatic content at higher ratio produced more carbon residue. Higher aromatic content could also be a cause for the reduction of cetane number. It was confirmed that 2:1 was the optimum ratio to produce better pyrolytic oil with less aqueous product which was less viscous, have good flow ability at low temperature (>5 °C) and higher calorific value pyrolytic oil compared to thermal pyrolytic oil. The calorific value of co-pyrolytic oil at 2:1 ratio was quite similar to that of diesel which can be used as fuel in combustion engine. Moreover, the comparison between thermal, catalytic and co-pyrolysis confirmed that co-pyrolysis of non-edible seeds with waste polystyrene was one of the easiest methods to enhance the fuel properties of pyrolytic oil compared to others.