CONCLUSION AND FUTURE RECOMMENDATIONS

This chapter contains the conclusions of work done in the light of broad objective of the thesis “Performance evaluation of conversion process of biomass to bio-oil production through Pyrolysis technique”. Study shows that selected biomass (soya husk, rice husk, bagasse, cotton stalk and wood saw dust) could be the viable source of bio-oil production. Gas heating based along pretreated pyrolysis technique for bio-oil production could be promising alternative source to enhance the production of bio-oil.

On the basis of the research work conducted in this project, the following conclusions are drawn:

[1] The selection of biomass is important because bio-oil production highly affected with pyrolysis feed materials. Selected biomass should be rich source of cellulose, hemicellulose and lignin; however sulfur and nitrogen content should be as low as possible.

[2] FTIR analysis of biomass indicate that biomass is a good source of aldehyde, carboxylic group, nitrogenous compounds, alkane, alkene group and phenol, which may be important compounds for pharmaceutical and chemical products from bio-oil.

[3] Particle size of biomass is a one of the important parameter for bio-oil production. Smaller particle size (212 μm) of biomass found more effective for bio-oil production through Pyrolysis process.

[4] Bio-oil quality and chemical composition of oil was highly affected with pyrolysis temperature, heating rate, and biomass material. Operating parameters such as reactor temperature, heating rate, sweep gas flow rate and residence time of reactor was found optimum as 600°C, 20 °C/min, 20 ml/min and 30 minutes respectively for batch type slow pyrolysis process. Highest bio-oil production (23.52 %) was obtained in soya husk biomass followed by wood saw dust (22.41 %), which may be due to higher carbon (42.97 %) in soya husk biomass.

[5] The empirical mass formula developed for different bio-oils (Soya husk bio-oils - CH₁₅₈N₀.₀₁O₀.₇; rice husk bio-oils- CH₈₈N₀.₀₆O₄.₄₄; cotton stalk bio-oils-
CH$_{1.75}$N$_{0.05}$O$_{1.01}$; wood saw dust bio-oils- CH$_{9.6}$N$_{0.05}$O$_{5.36}$ and bagasse bio-oil CH$_{9.2}$N$_{0.05}$O$_{5}$) also confirm that quality and quantity of bio-oil are affected by mainly hydrocarbon and oxygen.

[6] Tubular fixed bed electrical heating reactor was found convenient to use, however it was not cost feasible. LPG based tubular fixed bed reactor was found cost effective.


[8] In general treatment of biomass increased the production of bio-oil, pretreatment of biomass with NaOH breaks the chemical bonds which allows the release of volatile matter at a shorter temperature and hence responsible for increased volatile matter and finally production of bio-oil. Biomass treated with iron dust (biomass: iron dust; 4:1) gave higher output of bio-oil (wood saw dust, produced 69 %) compared to NaOH (wood saw dust, 53 %) as well as untreated biomass.

[9] pH value of all the tested bio-oils fall in the acidic range (2.5 - 4.9), which indicate the need for neutralization, if it has to be used for engine applications.

[10] All the bio-oil found from soya husk, rice husk, bagasse, cotton stalk and wood saw dust had higher viscosity and density, which indicate that it needs to be treated before the end applications.

[11] Analysis of bio-oils (Gas chromatography- mass spectroscopy analysis) indicated major presence of phenol and phenol derivatives chemical compounds; however benzene and benzene derivatives were also found. Activation analysis of charcoal indicated better utilization of charcoal. Hence, charcoal may be activated, for its better and economical utilization.

[12] Bio-oils obtained through Pyrolysis are highly acidic in nature, which caused problems during end application. Blending with methanol and ethanol could neutralize acidity of bio-oil. Blending of bio-oil with methanol/ethanol also improve the thermal and chemical characteristics of bio-oil.

[13] The storage study of bio-oil indicate that bio-oils could not be stored even for 6 months as the viscosity, density, pH value, ash content of bio-oil increased up to 62.07-152.45 %, 1.06 - 15.18 %, 5.85 - 55.24 %, 23.50 - 283.34 % respectively. Ultimately ash content was responsible for lower heating value of bio-oil.
Ageing study (at 60°C temperature for 15 days) indicate that pH value of bio-oil could be improve, if it is aged with methanol blended bio-oil, as methanol react with bio-oil and stopped the chemical reactions, thus bio-oil could not polymerize, however with increase of aging time pH value slightly decreased.

Combustion study indicate that bio-oil could be used as cooking fuel in pressure stove with blend of 20% bio oil and 80% methanol without any problems.

The Bio-oil production cost using an electrical based heating system of pyro reactor was observed to be very high (Rs.220.41/kg), even after the treatment of biomass with NaOH and iron dust. Bio-oil production cost could be reduced drastically using LPG based heating system of pyro reactor and using treated biomass (Rs. 12.06 / kg).

Considering the by-product of Pyrolysis process and upgrading the charcoal into activated charcoal could further reduce operating cost of bio-oil.

8.1 RESULTS, WHICH CAN BE EXPLOITED ON PILOT OR FIELD SCALE

The following results can be exploited on pilot scale
1. Gas heating tubular fixed bed pyrolysis reactor with iron dust treated biomass could be tried on pilot or field scale level.
2. Charcoal activation cost could be reduced, if obtained charcoal through pyro reactor is done on pilot scale basis, which will further reduced the bio-oil production cost.

8.2 FUTURE RECOMMENDATIONS
1. Other catalyst such as HZSM-5, HZSM could be used for treatment of biomass as these catalysts also improve the bio-oil quality.
2. Using the pyrogas obtained during the Pyrolysis process, continuous Pyrolysis reactor could be developed.
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