Analytical and Applied Pyrolysis of Challenging Biomass Feedstocks: Effect of Pyrolysis Conditions on Product Yield and Composition

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Highlights

- Two different reactors: Single particle reactor (SPR), microwave pyrolysis (MWP) were employed.
- The heating rate in pyrolysis reactors followed the trend: SPR > MWP
- Condensable yield was higher in SPR (48-63 wt.%) than MWP (21-31 wt.%)

1. Introduction

The literature survey [1-3] shows that a systematic comparison of the different pyrolysis methods for diverse biomass feedstocks is necessary, viz rice straw (RS) and empty fruit bunch (EFB) from India and pine bark (PB) and birch bark (BB) from Finland. The present study is the first to utilize two different techniques, i.e. SPR, and MWP, to study pyrolysis of four different challenging biomass feedstocks: RS, EFB, PB, and BB. The objective of the study is to perform detailed chemical characterization of the biomass feedstocks and investigate the effect of heating mechanisms and rates as well as the chemical composition of the feedstocks on the pyrolysis product yields and compositions. The aim, in the long run, is to generate the necessary information for the design and development of pyrolysis technologies for challenging biomass feedstocks.

2. Methods

Three different types of reactor were used to investigate the effect of temperature and heating mechanism on product yield and composition during the pyrolysis of biomass.

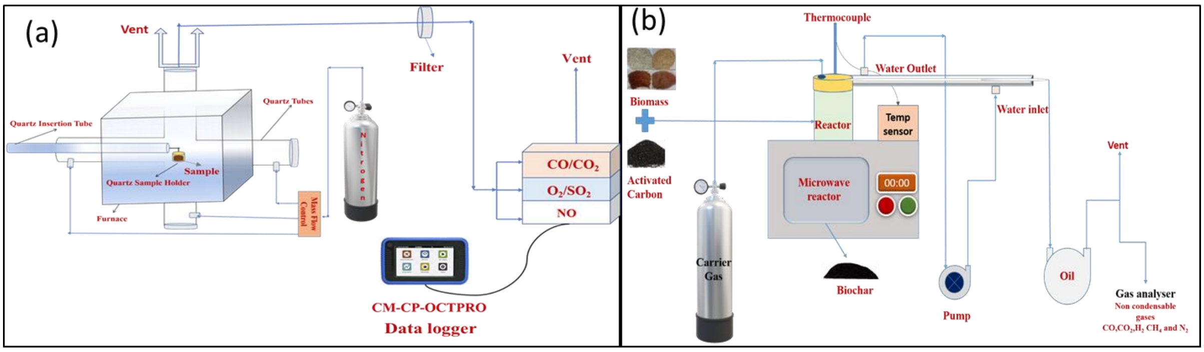

Figure 1. Schematic diagram of reactor setup used in the study (a) single particle reactor (SPR) and (b) microwave pyrolysis reactor (MWP

For a typical pyrolysis experiment, the SPR was first heated to the desired pyrolysis temperature, and N2 gas was supplied to the reactor from the bottom and side ports at a total flow rate of 3.67 L min-1. Then, a sample pellet of about 150 mg and 10 mm in diameter was placed in a quartz-glass-sample holder, and the sample holder was mounted on the sample insertion probe shown in Fig. 1 (a). The sample was then inserted into the hot reactor and pyrolyzed. Microwave pyrolysis experiments (shown in figure 2(b) were performed at 500°C and 600 W for individual biomasses (RS, EFB, PB, and BB) using activated carbon as susceptor in a feed-to susceptor mass ratio of 5:1. The purpose of selecting this temperature (500°C) was to compare the product yields and oil compositions from microwave pyrolysis to single particle pyrolysis, where the condensable oil yields were the highest for all biomasses except RS. Typically, the experiment employed 20 g of biomass sample and 4 g of activated carbon susceptor.

3. Results and discussion

The product yield form microwave pyrolysis (MWP) and single particle rector (SPR) at 500°C is shown in figure 2. The solid, liquid and gas yield depends on heating rate. The gas yield in MWP was 50-60% higher compared to SPR due to generation of localized hotspot during microwave heating of the biomass and formation of more gases takes place.

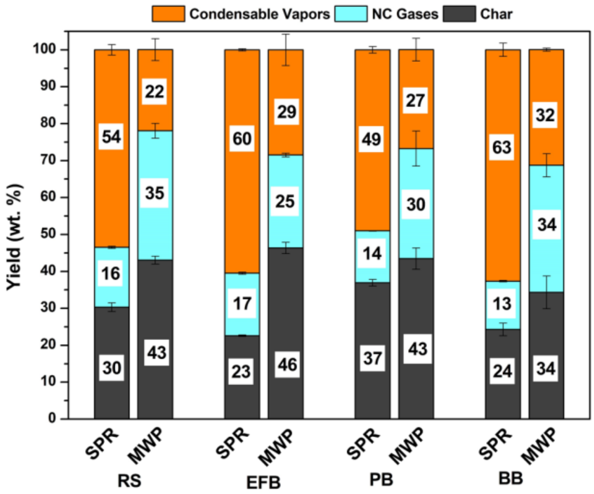

Figure 2. Product yield form microwave pyrolysis and single particle rector at 500°C.

The liquid yield from SPR was almost twice of MWP which is attributed to the faster heating rate in SPR compared to MWP. The char yield was lower in case of MWP due to lower heating rate.

4. Conclusions

In this study, a round-robin chemical and thermal characterization of two agricultural residues (RS and EFB) and two wood barks (PB and BB) were carried out at IITM and ÅA laboratories. Results of the round-robin chemical analyses of the biomass samples showed a good reproducibility of the experiments. The DSC-TGA results showed that the hemicellulose, cellulose, and lignin components of the samples decomposed in different but overlapping temperature ranges, owing to differences in their chemical structures. The condensable pyrolytic gas ("bio-oil") yields obtained from pyrolysis of the samples in the single particle reactor (SPR) were the highest at 500 °C. However, the biochar yields decreased, and the CO+CO2 gas yields increased as the pyrolysis temperature was increased from 400 to 600 °C. Low bio-oil yields and high biochar and CO+CO2 gas yields were obtained from the MWP at 500 °C compared to the corresponding yields obtained from the SPR at the same temperature due to the slow heating rate in the MWP. From pyrolysis of the samples at 500 °C in both the SPR and microwave, the highest bio-oil and lowest biochar yields were obtained from the BB, owing to its low ash content.

References

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