Effect of Mechanical Pressure on the Carbonization Behavior of Woody Biomass Wastes

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Highlights

- The carbonization behaviors of cold press pellet and hot press semi-char were examined.
- The char yield at 900^{o}C of hot press semi-char was increased to 27.7 wt%, while the char yield of power biomass was only 17.0 wt%.
- The dehydration reaction was accelerated by hot press carbonization and the mechanical pressure suppresses the evolution of tar components, thus resulted in increase of the char.

1. Introduction

Biomass is a renewable resource and its effective utilization is indispensable, particularly in Thailand, where massive amounts of biomass wastes are generated. Biomass is classified as a low-grade fuel which naturally contains undesired properties, such as high moisture content, high ash content and low energy density [1]. On the other hand, charcoal from wood derived biomass is regarded as candidates for low priced raw materials for activated carbons. However, the yield of charcoal from biomass wastes is low in general. So, it is essential to develop a method to increase the yield of charcoal during the carbonization of biomass wastes. In this study, Leucaena, which is woody biomass, were pressurized at around 500 MPa at room temperature, called cold press in this work, to prepare a biomass pellet. Leucaena was also pre-carbonized under mechanical pressure of around 70 MPa at the temperature range of 25^{o}C to around 250^{o}C, called hot press in this work, to prepare densified semi-chars. Then, both cold press pellets and hot press semi-chars were subjected to carbonization at around 900^{o}C to examine the effect of mechanical pressure on the carbonization of leucaena.

2. Methods

2.1 Sample: Woody biomass (*Leucaena Leucocephala*) was selected as a sample. It was firstly shredded with cutting mill and ground with a ball mill in order to obtain the sample particle size less than 75 μm. Then, it was dried in vacuo at 70^{o}C for 24 h before the experiment.
2.2 Cold Press Pellet: Around 400 mg of leucaena powder was pressurized at around 500 MPa at room temperature using a hydraulic press, called cold press in this work, to prepare a biomass pellet.
2.3 Hot Press Carbonization: Around 1.5 g of leucaena powder was placed between the molds, heated by electrical furnace at the rate of 10 K/min to a final temperature of 250^{o}C and the sample was maintained at this temperature for 10 min. The mechanical pressure of 70 MPa was loaded during this carbonization stage. After that, the furnace was turned off and the reactor was cooled rapidly under the load.
2.4 Carbonization experiment: The carbonization experiments were performed using a thermobalance (TGA-50, Shimadzu). The biomass sample was heated from room temperature to 900^{o}C at the heating rate of 10 K/min under nitrogen atmosphere.
2.5 Analysis of gas formation rates during the carbonization: A quadrupole mass spectrometer (Perkin-Elmer, Clarus 500 MS) coupled to the thermobalance (Perkin-Elmer, Pyris1 TGA) was used for the evolved gas analysis. To avoid secondary reactions, a probe was placed very close to the sample pan of the thermobalance in the direction of the gas flow. The transfer lines between the TGA and MS were heated to 200^{o}C in order to avoid cold spots and thus prevent the condensation of the gaseous products. The signals for mass numbers of 2, 15, 18, 28, and 44 were continuously detected. Then, the mass numbers were converted to the concentrations of H_2, CH_4, H_2O, CO, and CO_2 by referring to the calibration curves constructed using the standard gases. The evolving rates of the gaseous products were estimated from the measurements.

3. Results and discussion

3.1 Change in weight during the carbonization

Figure 1 shows the weight changes of raw, cold press pellet, and hot press semi-char prepared from leucaena during the carbonization. The starting point of the hot press semi-char was equal to the yield of semi-char during the carbonization under mechanical pressure. It was found that the char yield at 900^{o}C of cold press was 21.9 wt%, while the char yield of powder leucaena was only 17.0 wt%. On the other hand, the char yield of hot press semi-char was surprisingly increased to 27.7 wt%.

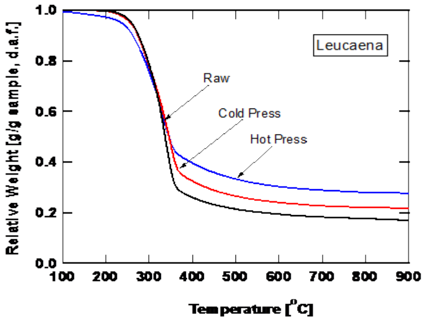

Figure 1 TGA curves during the carbonization of raw, cold press pellet, and hot press semi-

3.2 Change in gas and tar formation rate during the carbonization

Figure 2 compares the formation rates of gaseous products and tar during the carbonization between the powder leucaena and the hot press semi-char. Most significant difference between the powder leucaena and the hot press semi-char is the tar formation behavior. For the powder leucaena, a large tar formation peak appeared at around 320 ^{o}C, which was accounted for 0.40 g/g-biomass. On the other hand, the amount of tar formed was only 0.19 g/g-biomass for the semi-char prepared by hot press carbonization. This indicated that the tar formation was suppressed by the hot press carbonization.

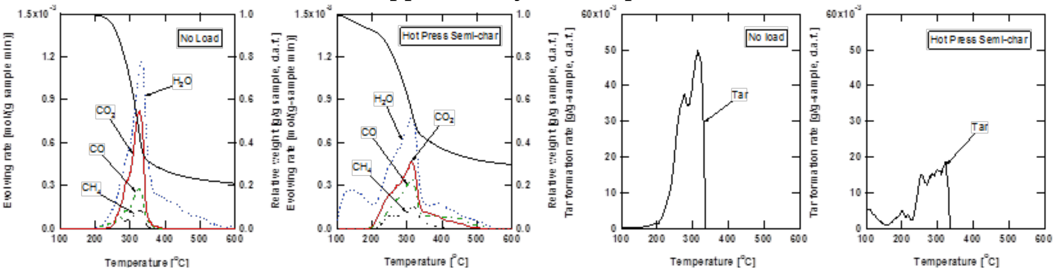

Figure. 2 Gas and tar formation rates during the carbonization of raw and hot press semi-char.

4. Conclusions

We examined the effects of mechanical pressure on the char yield during the carbonization of woody biomass. Leucaena was pressurized at around 500 MPa at room temperature, called cold press in this work, to prepare a biomass pellet. Leucaena was also pre-carbonized under mechanical pressure of around 70 MPa at the temperature range of 25^{o}C to around 250^{o}C, called hot press in this work, to prepare densified semi-chars. Then, both cold press pellets and hot press semi-chars were subjected to carbonization at around 900^{o}C to examine the effect of mechanical pressure on the carbonization of leucaena. It was found that the dehydration reaction was accelerated by hot press carbonization and the mechanical pressure suppresses the evolution of tar components. Therefore, the mechanical pressure is judged to be effective to increase the char yield through the carbonization of biomass.

References

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Keywords
Biomass, Mechanical Pressure, Carbonization, Torrefaction