CHAPTER 5

CONCLUSION

In this study, several experiments were conducted in order to get a sound understanding of the fundamentals of the pyrolysis process and the effects of pyrolysis at low temperature on the biomass properties. The pyrolysis behaviors of raw biomass were studied by the use of both TGA and TG-MS techniques. From TGA, the weight loss curves of all studied biomass were quite similar, especially when plotted on dry ash free basis. On the other hand, the pyrolysis behavior by TG-MS technique of each raw biomass showed the significant differences in weight loss profile and the evolving rate of each pyrolysis product. The differences were according to their chemical compositions: cellulose, hemicelluloses, lignin, extractive, and mineral matter. Apart from their chemical compositions, the chemical bonds have also played an important role. Focusing on the pyrolysis product, H_2O was the majority product gas of all studied sample pyrolysis, while CO and CO_2 were evolved less than H_2O. The early and high amount of H_2O released was from the early decomposition of significant amount of hemicelluloses (33.9 – 42.1 wt %) in biomass samples.

From fast pyrolysis, the carbon contents in torrefied biomass were found to be increased, the oxygen and hydrogen contents were found to be decreased and the nitrogen content was quite constant when increasing the pyrolysis temperature and retention time. All fast pyrolysis conditions, gave the torrefied biomass with very little increases in carbon contents and calorific values but significant decreases in solid yields. Fast pyrolysis at 300°C with 100s retention time was found as the best condition among all fast pyrolysis conditions. From this condition, torrefied jatropha trunk has the highest increase in calorific value among all studied samples. Its calorific value was increased by about 8.9% while its solid yield was decreased by about 50.0% by weight. Apart from fast pyrolysis, slow pyrolysis at 260°C and 280°C with 10°C/min heating rate and no holding time also gave the torrefied biomass higher carbon contents which led to their higher calorific values in comparison to raw biomass. The carbon contents and calorific values were also found to increase with increasing the pyrolysis temperature. Considering both solid yield and heating value, slow pyrolysis gave the torrefied products more significant increase in calorific values but lower decrease in solid yields compared to fast pyrolysis. The calorific value of torrefied jatropha trunk from slow pyrolysis at 280°C was increased by about 16.2% while its solid yield was decreased by only about 30.0% by weight. Apart from ultimate analyses and calorific value calculations, the diagrams plotted between H/C and O/C also indicated that the elementary compositions of torrefied biomass were moved toward Mae moh lignite. The elementary compositions of torrefied biomass from slow pyrolysis have more significant change from raw biomass than fast pyrolysis. The relationships between torrefied solid yields and calorific values implied that to reach the same value of heating value, slow pyrolysis gave a higher torrefied solid yield than fast pyrolysis. By the use of energy density as an indicator, slow pyrolysis at 280°C was found to the best condition among all studied conditions which gave the torrefied solid the highest energy density. Torrefied napier grass from this condition has the highest energy density which is about 1.21at the torrefied yield almost 70.0% by weight.

During the slow pyrolysis, some gas and light liquid products were released. Solid product was observed as the majority product and H_2O was observed as the majority gas product. Liquid product or light tar was considered as acetic acid which is a light hydrocarbon compound released during low temperature pyrolysis. The solid product was found to decrease when increasing the pyrolysis temperature. On the other hand, the volatiles and light liquid products were found to increase with increasing temperature. From slow pyrolysis at low temperature, both mass and energy yields of biomass samples were decreased. It was found that the loss in energy yield was less than the loss in mass yield. This can be explained by the fact that the majority of released products were from hemicelluloses decomposition which contains low energy such as H_2O and CO_2. Moreover, the results from proximate analyses showed an increase in percentages of fixed carbon and ash but a decrease in volatile matter of torrefied biomass from both temperatures of slow pyrolysis. The increasing in fixed carbon and decreasing in volatile matter led to the increasing in fuel ratios of torrefied biomass which made them more favorable than raw biomass. The overall energy balances of slow pyrolysis indicated that these processes were endothermic reactions which required some energy during the process. The differences between energy input and energy output were found to increase with increasing pyrolysis temperature and they were in the range between 112 – 1,114 kJ/kg. From combustion behavior study, the combustion behaviors of almost torrefied biomass were changed from raw biomass, except for napier grass which showed quit similar behaviors. Torrefied biomass start to be decomposed at higher temperature in comparison to raw biomass due to their preliminary decomposition during pyrolysis. The volatile combustion of torrefied biomass occurred in the narrower range of time and combustion temperature. And for char combustion, torrefied biomass also showed the higher char combustion rate compared to raw biomass.