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SLOW PYROLYSIS OF SELECTED AGRICULTURAL WASTES: ANALYSIS OF THERMAL DEGRADATION BEHAVIOR

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ABSTRACT

The use of fossil fuels produces carbon dioxide (CO_2). Carbon dioxide is one of the greenhouse gasses that contributes to global climate change. Due to this issue, there is increasing the requirement for the use of renewable materials and development of the additional sustainable process. Agricultural waste that has the property of fast growth, is an alternative renewable energy. In this work the slow pyrolysis of selected agricultural wastes mixture (cassava peel-rice straw, rice straw-rice husk, and cassava peel-rice husk) were studied to determine thermal degradation behavior of the biomass. The process was conducted in a fixed bed reactor at temperatures 325 °C, at 10 °C/min heating rate and at 10 min holding time. Results revealed that the moisture content of agricultural wastes were 4.40 % (cassava peel-rice husk), 5.48 % (rice straw-rice husk) and 8.12 % (cassava peel-rice straw). The devolatilization process of the biomass was taken place in the temperature range from 189 °C to 325 °C. The volatile matter of each sample was 61.5% for cassava peel-rice husk, 58.5 % for rice straw-rice husk and 52.5 % for cassava peel-rice straw.

Keywords: agricultural, waste, energy, renewable

1 INTRODUCTION

One major source of energy in the world is biomass. In 2010, the 12,2 % of global primary energy consumption was provided by biomass (REN21 2012). Many agricultural wastes are generated each year in Indonesia. Agricultural waste is waste produced as a result of various agricultural operations. Some of the agricultural wastes are rice straw, cassava peel, rice husk, sawdust, corncob and many others. A number of agricultural wastes can be converted to an amount of green energy. Briquetting is the process to convert agricultural waste into uniformly shaped that are easy to use, transport and store (Raju 2014). Briquetting of agricultural waste biomass can increase the energy per unit volume. Diversification of energy resources and the environmental awareness concerning climate change are some of the factors when developing alternative fuels for domestic.

Several studies on the pyrolysis of biomass have recently been reported in the literature. Laidy (2014) and her co-workers use bamboo (species *Dendrocalamus giganteus* Munro) as

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biomass to obtain biochar properties by slow pyrolysis process. The process was conducted in a fixed bed reactor at temperatures ranging from 300 to 600 °C and at 10 °C/min heating rate.The bamboo biochar had suitable properties for its use as energy source and for agricultural applications.

Another work has been conducted by Ki et al. (2013) dealing with slow paralysis of cassava peel. In this work, cassava peel is used as raw material to produce bio-oil through slow pyrolysis process in a fixed-bed reactor. The effect of pyrolysis temperatures on the physicochemical properties of bio-oil was studied. The maximum yield of bio-oil ca. 51,20 % was obtained at 525 oC and the biofuel has a gross calorific value of 27,43 MJ/kg.

Mhilu (2015) examines biomass residues from pines and eucalyptus trees. The properties of sawdust materials were investigated by adopting proximate and ultimate analysis methods. The results revealed both pine and eucalyptus sawdust materials to have high O/C ratios hence, but with low H/C ratios, while their heating values are 152,446 kJ/mol, for pine and 157,576 kJ/mol, for eucalyptus. These results gave an indication that eucalyptus sawdust could be suitable for bio-oil production due to its high volatile level, while pine sawdust for syngas production since it contains high ash content.

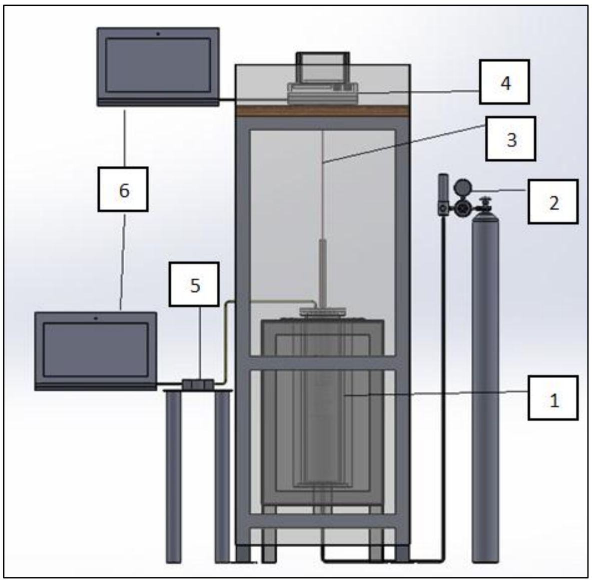
Phan (2008), the main products from slow pyrolysis of key segregated waste materials were characterized for mass yield, energy content, elemental composition, and chemical compounds. About 200 g of waste wood, cardboard or textile residues were pyrolysed in a small packed bed reactor at a final temperature ranging from 350 to 700 oC with a slow heating rate. The char contained about 38–55% of the energy content in the raw material. The difference in the properties of char between the materials was mainly due to the incombustible fraction that remained in the solid product. The pyrolysis liquids had a gross calorific value of about 10–12 MJ/kg, representing about 20–30% of the energy content in the raw material.

Pyrolysis of biomass can be described as direct thermal decomposition of the material in the absence of oxygen to obtain an array of solid (char), liquid (tar) and gas products (Oladeji et al. 2015). Pyrolysis agricultural waste produced tar, char, and an organic component. The thermal behavior of selected agricultural waste mixture as cassava peel-rice straw, rice straw–rice husk and cassava peel-rice husk was investigated using a pyrolysis test. This paper presents a slow pyrolysis test of agricultural wastes mixture to determine the drying temperature and devolatilization temperature of the biomass.

2 METHOD

Analysis of thermal degradation behavior of the selected agricultural wastes mixture (cassava peel-rice straw, rice straw-rice husk, and cassava peel-rice husk), was made by employing a pyrolysis test reactor (Fig. 1) to study mass loss characteristics of the materials when heated under inert condition. The pyrolysis test reactor consists of a balance with a pan loaded with the sample. The pan is placed in a heated oven with a thermocouple to measure the temperature. The mass loss and the temperature rises will be processed graphically to determine the thermal decomposition profile and the rate of mass reduction.

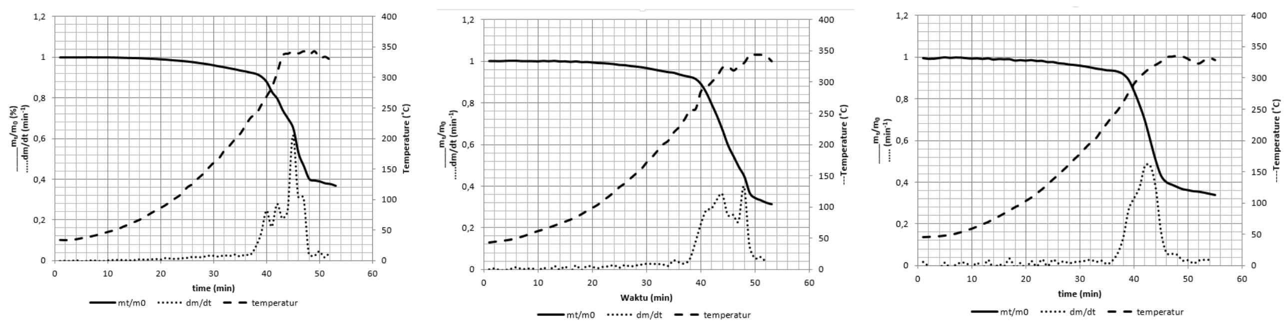
The biomass samples were dried to the moisture content of 12 % and sieved to the mesh size of 20 before the analysis was made. In order to avoid combustion during the experiment, a gas of pure Nitrogen with a flow rate of 100 ml/min was supplied to remove air in the pyrolysis test reactor. Subsequently, each sample of 20 gr was put in the reactor. The heating rate adopted was 10 ^{o}C/min and the samples were heated from room temperature to 325^{o}C.



1. Reactor
2. Nitrogen gas
3. Connection wire
4. Balance
5. Data acquisition
6. Laptop

Figure 1. Fix bed pyrolysis reactor

3 RESULTS AND DISCUSSION



(a) (b) (c)

Figure 2. Thermal degradation of (a) cassava peel-rice straw (b) cassava peel-rice husk (c) rice husk-rice straw

The experiments were conducted at the constant heating rate, as the temperature was raised from room temperature to 325^{o}C. The heating rate used in this study was 10 ^{o}C/min. Weight change of a sample is recorded as a function of time. The curves in Fig. 2 give information on thermal decomposition behavior of biomass pyrolytic conditions. The curves showed that there were two zones of decomposition. The first zone corresponds to the drying process where the sample loss of moisture content. At the temperature up to 200°C, the shape of the curve shows the drying process. It can be concluded from the curves that in the drying process, all the samples lost their weight in the range of 4-8%, where rice straw-rice husk has recorded the highest mass loss. The moisture content of agricultural wastes was 4.4 % for cassava peel-rice husk, 5.48 % for rice straw-rice husk and 8.12 % for cassava peel-rice straw.

Devolatilization is the major step in all thermo-chemical conversion process involving biomass. This step is represented by the second stage of decomposition were the remarkable slope of the curves is observed, corresponding to the significant drop in weight of samples due to the liberation of volatile matter. The devolatilization process of the biomass was taken place in the temperature range from 189 to 325 ^{o}C. In this process, all the samples lost their weight in the range of 52-62%. In the present analysis cassava peel-rice husk found highest mass loss percentage (61.5%). The volatile matter of each sample was 61.5 % for cassava peel-rice husk, 58.5 % for rice straw-rice husk and 52.5 % for cassava peel-rice straw.

4 CONCLUSION

Pyrolysis test has been performed for three selected agricultural wastes mixture samples which can be used as the briquetting raw material. The thermal behavior of selected agricultural wastes mixture was investigated by using pyrolysis test. It can be concluded that the moisture content of agricultural wastes mixture was 4.40 % for cassava peel-rice husk, 5.48 % for rice straw-rice husk and 8.12 % for cassava peel-rice straw. The volatile matter of each sample was 61.50 % for cassava peel-rice husk, 58.5 % for rice straw-rice husk and 52.5 % for cassava peel-rice straw. These results gave an indication that agricultural wastes could be suitable for biomass briquette. The use of renewable energy can reduce carbon emissions and greenhouse gasses, and therefore, reduce global warming and climate change.

5 ACKNOWLEDGEMENTS

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