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Pyrolysis of empty fruit bunch by thermogravimetric analysis

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Abstract

The purpose of this paper is to study the characteristics of as received and wet-treated empty fruit bunch (EFB) for bio-oil production via pyrolysis technology. The elemental properties of the feedstock were characterized by an elemental analyzer while thermal properties were investigated using thermogravimetric analyzer (TGA). The pyrolysis process was being carried out at room temperature up to 700°C in the presence of nitrogen gas flowing at 150 ml/min. The investigated parameters are particle sizes and heating rate. The particle sizes varied in the range of $dp_1 < 0.25$ mm and $0.25 \leq dp_2 < 0.30$ mm. The heating rates used were 50°C/min and 80°C/min. From the results obtain, smaller particle size dp_1 produces 10% less char yields, while higher heating rate of 80°C/min increases rate of decomposition by almost 1 mg/s. Treatment process reduces char yields of dp_2 by a total of 5%. This study can provide an important basis in determining suitable properties of EFB and pyrolysis parameter for bio-fuel production via pyrolysis.

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Keywords: Empty fruit bunch (EFB); Thermogravimetric analyses (TGA); Characterization; Thermal degradation; pyrolysis

1. Introduction

Biomass is defined as the products fraction of biological degradable, waste and residues are from agriculture which including animal and vegetable materials, forestry and the biological degradable fraction of industrial and household waste [1]. Biomass in the form of biomass energy is one of largest contributor to the world economy. The technology of converting biomass into energy is a right option since it is a renewable type of energy source that could dramatically improve the environment, economy and energy security. Pyrolysis is one of the most promising technologies of biomass utilization, and it is also the first stage of biomass thermochemical conversion. By pyrolysis, biomass is converted into liquid

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oil, char and gases. In the absence of oxygen, the yields and compositions of pyrolysis products depends on the type of biomass, temperature, heating rates, type of reactors, particles size and co-reactant [2]. The objective of this study is to investigate the pyrolysis of as received and wet-treated palm oil empty fruit bunch (EFB) by thermogravimetric analysis. In addition, the thermal degradation of EFB also is studied. These analyses will provide important information for potential biofuels production from EFB.

2.0 Materials and experimental procedures

2.1 Materials preparation and characterization

EFB used in this experiment was supplied by Malaysian Palm Oil Board (MPOB). The feedstock were first milled and sieved into smaller particle size of <0.30 mm. Wet-treated EFB was prepared by hot wash to reduce mineral in the biomass such as sulphur, magnesium, calcium and aluminium. It was done to investigate the effect of ash in biomass decomposition. 2 g of sample were stirred in a beaker with 150 ml of deionized water at 353 K for 2 hours. The suspension was then filtered and washed with 300 ml of distilled water before being dried in a desiccator under vacuum condition at room temperature. The characterization of EFB was performed in order to obtain its ultimate, proximate and high heating value (HHV). The ultimate analysis was carried out using elemental analyzer which determines the amount of C, H, O, N and S in the feedstock. The proximate analysis was conducted using thermogravimetry analyzers (TGA) to analyze volatile matter (VM), fixed carbon (FC), moisture content and ash content in EFB. The HHV of EFB was determined using bomb calorimeter.

2.2 Experimental procedures

TGA was carried out in the presence of nitrogen (N_2) at the flowing rate of 150 ml/min. EFB samples between 0.5 and 1.0 g were pyrolyzed to a maximum temperature of 700°C. The sample was first heated to 110°C and kept at that temperature for 30 minutes to remove any moisture. After that, the samples were individually heated at 50°C/min and 80°C/min until 700°C. The experiment was repeated for each as received and wet-treated EFB at different particle size ($dp_1 < 0.25$ mm and $0.25 \leq dp_2 < 0.30$ mm).

3.0 Results and discussion

3.1 Properties and composition of feedstock

From the analysis, moisture contents for both as received and wet-treated samples vary with only 0.1% difference. Higher moisture content usually contributed to a lower amount of volatile matter since more heat are needed to first volatize the water before decomposing the biomass. The treatment process results in a higher carbon value in the wet-treated sample. It was shown through the ultimate analysis of the wet-treated sample where it contains 45.36% of carbon as compared to 44.71% in as received sample. The amount of nitrogen also increases by 0.11% while the amount of hydrogen drops about 0.33%. The treatment process did not change the amount of sulphur in the sample as it remained with 0.41%. The amount of ash in wet-treated product was slightly lesser compared to as received EFB due to removal of some alkali metal during washing process. The properties and composition of as received and wet-treated EFB are presented in the Table 1 below:

Table 1. Properties of empty fruit bunch

Analysis		As received	Wet -Treated
Proximate analysis (db wt %)	Moisture content	2.40	2.30
	Ash content	4.02	3.14
	Volatile matter	80.89	73.20
	Fixed Carbon	12.60	21.36
	High heating value (HHV) (MJ/Kg)	21.77	18.51
Ultimate analysis (db wt %)	Carbon (C)	44.71	45.36
	Hydrogen(H)	6.76	6.43
	Nitrogen (N)	0.21	0.32
	Sulphur (S)	0.41	0.41

3.2 Experimental results

All experimental results are plotted as a function of temperature, as shown in Fig. 1:

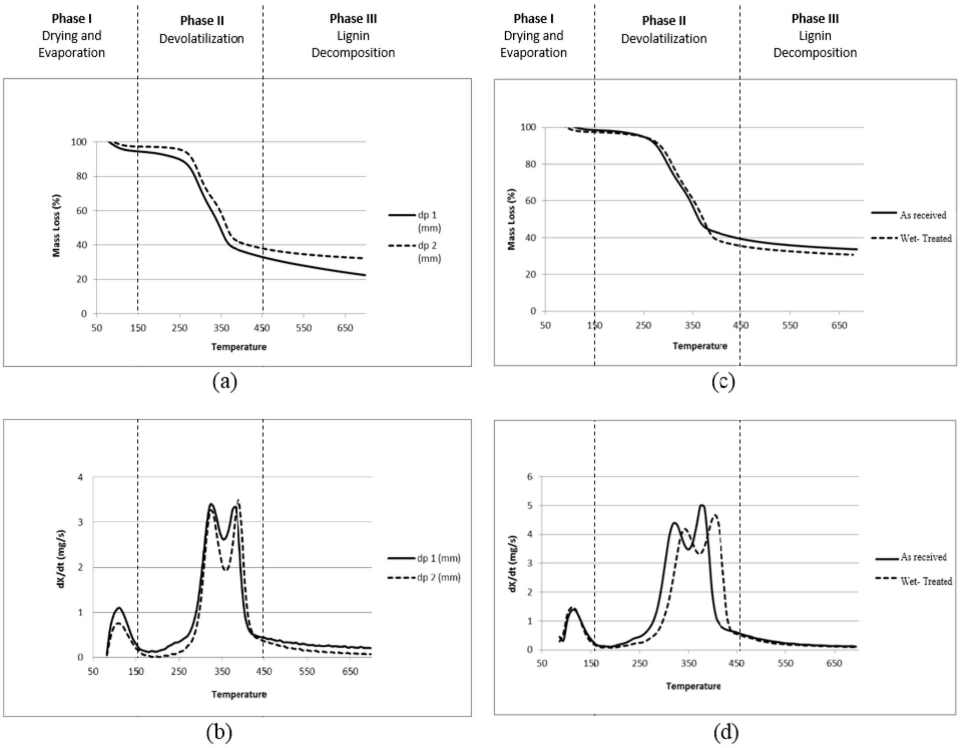

Fig. 1. A plot of (a) TGA and (b) DTG for dp_1 and dp_2 at 50 °C/min, (c) TGA and (d) DTG for as received and wet-treated EFB (dp_2) at heating rate of 80 °C/min.

In general, the pyrolysis of EFB can be divided into three phases which are drying and evaporation of light components (phase 1), devolatilization of hemicellulose and cellulose (phase 2) and decomposition of lignin (phase 3). Phase I occurs at temperature below 150 °C, phase 2 starts to devolatize from 150-450 °C and finally phase 3 is attains at temperature above 450 °C. Increasing particles size shifts the pyrolysis process to a higher temperature range and resulted in higher char yield because larger particles heat up un-uniformly. Poor heat transfer to the inner surfaces leads to low average particles temperature hence the yield of volatiles will be reduced [3,4]. Final char residues left at 700°C is approximately 22.3% for dp_1 and 32.30% for dp_2. No lignin decomposition was observed in either sample. Since EFB in general contains 82.4 % of hollocellulose and 17.6 of % lignin [5], certain amount of cellulose and hemicellulose were present in char content. From Fig.1 (b), as particle size increases from dp_1 to dp_2, DTG-peak shifted to right for approximately 15 °C.

Treatment process decreases the char production by 5% as recorded in Fig. 1 (c) due to alkali metal removal. From Fig. 1 (d), the height of DTG-peaks for wet-treated EFB decreases while the width increases although the moisture contents for both samples are almost similar. A DTG-peak for treated EFB shifts 30°C higher than as received sample. This pattern was also reported by Stenseng *et al.* [6]. It was observed that heating rates affect the shape of the peaks. Increases in heating rates shifted the main peak on the DTG profile to the lower temperature. At 310°C, the degradation peak of 80°C/min heating rate was higher than 50°C/min. The difference is almost 1 mg/s. At higher heating rates, quick fragmentation of biomass enhances the yield of volatiles. Rapid heating enhances volatiles abundance by fast endothermic decomposition of biomass, thus minimizes the time available for secondary reactions like tars cracking or repolymerization [7].

4.0 Conclusion

There are many factors influencing the pyrolysis process. The main factors discussed in this research are the effect of particle size, heating rate and properties of biomass itself. It can be concluded from this study that smaller particle size produces 10% less char than bigger particle size. Higher heating rate on the other hand increases the peak of the degradation rate by almost 1mg/s. Hot-wash treatment process shifted the DTG curve to the right by 30 °C although the moisture content only vary by 0.1%, which may due to the effect of alkali metal removal, but the process decreases char production for dp_2 by 5%.

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Biography

Dr. Norazana Ibrahim is a senior lecturer at the Faculty of Petroleum and Renewable Energy Engineering, Universiti Teknologi Malaysia. She has co-authored over 20 publications. Her current field of interest are: 1) Biofuels from biomasses; 2) Alternative and renewable energy; and 3) Hydrogen production for fuel cell: simulation and modelling.

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Noorhaza Alias earned her bachelor's degree from International Islamic University Malaysia in 2011. She is currently a graduate student under the supervision of Dr. Norazana Ibrahim and Dr. Mohd. Kamaruddin Abd. Hamid. Her project centers on bio-oil production via flash pyrolysis.