Thermal Investigation of Palm Kernel Shell (PKS) with Coal Bottom Ash in Thermo Gravimetric Analyser (TGA) in Inert Atmosphere

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Abstract

The aim of this experimental work to investigate the effect of Coal bottom ash (CBA) on thermal degradation of palm kernel shell (PKS). Thermal decomposition for 50 and 25 % CBA percentage in PKS samples were carried out it thermo gravimetric analyser (TGA) in non isothermal condition. The effect on the weight loss in the different region for 50 % and 25 % of CBA was investigated and found weight loss % increased by decreasing CBA percentage. It was observed the weight loss for 25 % CBA was 10.5 and 32.81 % at temperature region 0-260 and 250 -650 °C.Whereas, weight loss % was 8.8 and 27.6 % in the same temperature regions for 50% CBA. On the other hand the weight loss was small for 25 % CBA than %0 % CBA at 650 °C. Secondly the residual was left 60.5 and 54 % for 50% and 25 % of CBA. Moreover DTG profile shows that the hemicelluloses decomposed at temperature above 270 °C and Calloused at 370 to 400 °C. It was investigated most of the weight loss and DTG rate was observed in the temperature range of 300 to 400 °C. This fundamental study for optimization of CBA % our current work in gasification.

Keywords: Biomass, TGA, Coal bottom Ash, Palm kernel shell, Decomposition.

1. Introduction

Biomass energy economy makes remarkable development during last decade [1]. The utilization of biomass is not only produced clean and environment friendly fuel as well as boosted the agriculture. In current energy picture, fossil fuel is life line of energy sector by sharing 81.1 % of total world energy production [2]. The most alarming situation is that 84 % of green houses come from burning of fossil fuel. According to international energy record, Carbon dioxide emission almost doubled from 1971 to 2011 about 14080 to 31342 million ton of CO_2 and will touched to 42200 million ton in 2035.Global climate change initiatives (GCCI) reported that green house severity impact reduced by 18 % in 2012[3]. Biomass is getting acceptance rapidly as an alternative source due to its abundant availability ,CO_2 neutrality and sustainability [4].

Biomass utilization is preferred over other alternative recourses due to its conversion into both liquid and gaseous fuel [5]. Biomass converted into fuel by both biological and thermochemical techniques. Gasification and pyrloysis [6] are the most efficient thermochemical method to produced bio oil and gaseous fuel production [7]. The efficiency of both process is directly related with biomass characteristics and use of catalyst [8]. It is very important to investigate the thermal degradation of biomass in the presence of catalyst that is related to heating value of fuel products [9].

Malaysia is tropical and agricultural country is rich in biomass residue. The main biomass are rice husk, oil palm, sugar cane, wood industry and solid municipal waste as shown in fig 1.2 [10]. Palm oil residue has become prior potential source by providing 85 % share of total biomass of country. South east Asia main producer of palm oil specially Malaysia and Indonesia are provides 87 % of total palm oil of world [10]. Malaysia has great potential of palm oil cultivation about 3 million hectors area are used for its cultivation [10] .The main biomass wastes produced during palm oil cultivation and its processing are palm kernel shell, trunks, fronds , empty fruit bunches and microscopic fibre. The total biomass waste production are 198 million ton/year which consist of 154.8 palm oil fronds (POF), 10.1 trunks, empty fruit bunches (EFB) 18.1, fibre 10.9 and palm kernel shells (PKS) are 4.2 million tons [11].

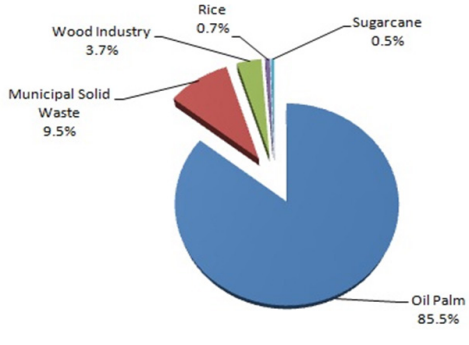

Figure 1 : Biomass waste distribution in Malaysia

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Many instruments and techniques are available to observe and understand the thermal degrading of biomass in presence of catalyst [7]. TGA proved to be very effective and reliable techniques and have numerous advantages. TGA make possible to monitor the mass loss with respect to time and temperature at specific heating rates [12]. Moreover, the precision, repeatability and collection of data at faster rate under controlled reaction condition is also provided by TGA [13].

Due to increases of utilization of palm oil waste for fuel production some researcher has made effort to study the thermal decomposition palm oil wastes. Khan et al. [14] studied the thermal decomposition of PKS and POF with heating arte of 20 ^{o}C/min and determine the kinetic parameter and activation energy in nitrogen environment. Yang et al. [15] was focused to investigate the thermal degradation of hemicelluloses and cellulose of EFB and PKS. He reported main degradation take place between 220 to 300 ^{o}C for hemicelluloses and 300- 400 ^{o}C for cellulose [15]. The thermal decomposition was effected by heating rate and derivative thermo gram has lateral shift by increasing the heating rate [16]. Siti et al. [17] studied the thermal decomposition of PKS, EFB with Malaysian low rank coal and determined kinetic parameter and developed a kinetic mode.

In recent years palm oil waste utilization increased for gasification. As Khan et al. [18] produced hydrogen from catalytic steam gasification of PKS. Inayat et al. [19] developed a kinetic model for H_2 production from catalytic steam gasification by using EFB [19]. Reza et al. used PKS with highly density polyethylene for syngas production in catalytic steam gasification [20]. Catalyst is very important in gasification process. Basically three types of catalyst are used in steam gasification namely, dolomite, nickel and alkaline earth metal [8]. The efficient and cheap catalyst is required. Coal bottom ash (CBA) is waste product of many industrial units. Ran et al. [21] characterized the CBA and reported the presence of alkaline metal content Al, Fe ,Ca, Mg and K [21]. These are prominent catalyst are used in steam gasification of biomass. Our recent work based on the utilization of coal bottom ash as a catalyst for gasification of biomass. According to author knowledge, thermal degrading study of PKS has not been reported with coal bottom ash. The purpose of this study to investigate the thermal decomposition of PKS with 25 % and 50 % blend of CBA. The change in weight loss at different temperature time region was studied for both cases. This fundamental study is very helpful in our recent work for use of CBA in biomass gasification.

2. Material and Methodology:

2.1 Material.

The biomass used in this study was PKS obtained from Kilang Sawit Felcra Nasarudin Sdn Bhd Malaysia. The biomass dried in sunlight for 3 to 4 days and further drying was achieved in oven to ensure the moisture removal. Proximate and ultimate analysis were performed using methods as described in previous publication [22] to determine the calorific value, elemental and component composition as shown in Table 1. Coal bottom ash was collected from TNB Janamanjung Sdn Bhd. power plant Selangor Malaysia. Both PKS and CBA were grounded and sieved in the size of 0.250 mm.

Table 1. Proximate and Ultimate Analysis of PKS

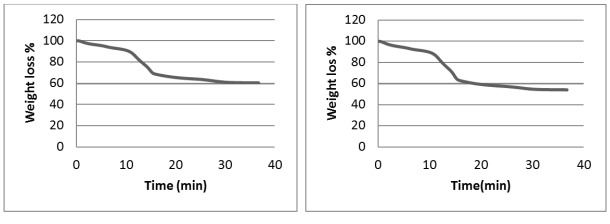
Proximate Analysis	
Moisture (%)	9.70
Volatile matter (%)	80.81
Fixed carbon (%)	13.81
Ash content (%)	4.48
Ultimate Analysis	
C (%)	48.61
H (%)	5.70
N (%)	1.01
S (%)	0.21
O (%) (by difference)	44.7
HHV(MJ/Kg)	18.82

2.2 Equipment and procedure.

The thermal degradation study was conducting in standard TGA (EXSTAR TG/DTA 6300, from SII). The sample was prepared with the 25% and 50 % of CBA content. The weight of sample about 10mg for each experiment was used. The flow rate of nitrogen was 100 ml/min used. Flow rate of nitrogen was kept content for 10 minutes at start to ensure the removal of entrapped gases. Sample was heated by heating rate of 25^{o}C/ minute up to 650 ^{o}C. The Temperature was kept constant for 10 minutes at 650 ^{o}C for gasification study at this temperature. All experiments are repeated three times to minimize the experimental error. There is no difference was observed in replicated runs.

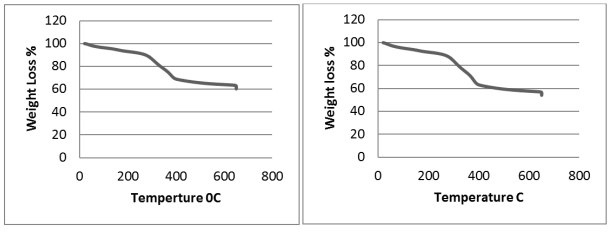
2.3 Result and discussion:

The thermal decomposition for 50 % CBA and 25 % CBA with PKS in terms of weight loss vs temperature and time are given in Fig. 2 and Fig. 3 respectively. It is clear from Figure 1(A) the weight loss was about 9.8 % for first 10 minutes for 50 % CBA. On the other hand the 50 % CBA shows 10.5 % mass loss in same time. The temperature change during this time was from 20 to 260 °C and 258 °C for 50 and 25 % CBA as shown in Fig. 3. It was observed that the weight losses were higher for 25 %. The weight loss during this period was due to drying process [14]. After drying the samples were heated up to 650 °C by heating rate 25 °C/minute as shown in Fig. 3. In pyrolysis zone the weight loss for 50 % CBA was 27.9 % and for 25 % CBA was 32.81 %. The weight loss percent (%) was still high for low percentage of CBA. It can be explained that the decomposition process was slows down in the presence of CBA. The most of weight lost due to evaporation of volatile matter. Both samples were kept contestant for 10 minutes at 650 °C the in order to study its behaviour in gasification environment. It is observed the weight loss was small for 25 % CBA in gasification region as shown in Fig. 2 and Fig. 3. It might be catalytic effect of CBA at higher temperature and the large quantity enhanced catalytic effect in biomass gasification process [21].



(A) (B)

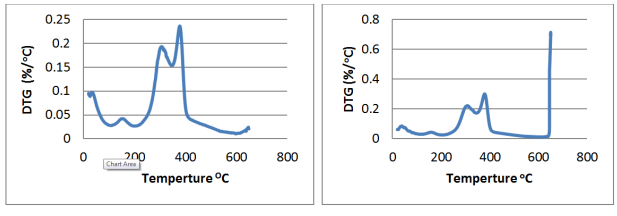
Figure 2 : Weight loss % Vs Time for (A) 50% CBA and (B) 25 % CBA



(A) (B)

Figure 3 : Weight loss % Vs Temperature for (A) 50% CBA and (B) 25 % CBA

Biomass material basically consists of hemicelluloses, cellulose and lignin. The order of thermal degrading for these component of biomass are as follow hemicelluloses >cellulose >lignin. The differential thermo gravimetric curve was shown in Fig. 4 for both 50 and 25 % CBA. There are two major peaks were observed in both cases at temperature range between 250-300 °C and 370 to 400 °C. The decomposition of hemicelluloses can be observed from first peak in both cases. The hemicelluloses decomposition occurred almost at same temperature region in both cases. But DTG was little bit higher for CBA 25 %. It might be due to higher percentage of PKS. The second peak shows the thermal degrading of cellulose in the temperature region of 370-400 °C. Lignin was decomposed at the end due to its morphology structure. The decomposition of cellulose and lignin at higher temperature was also reported in several studies [9, 16],[14]. At the gasification stage the sample containing CBA 25 % was showed an unusual peak of DTG. It might be due to higher biomass percentage. The higher percentage of CBA decreased the DTG rate per °C as compared to lower 25 % of CBA.



(A) (B)

Figure 4 : DTG % Vs Temperature for (A) 50% CBA and (B) 25 % CBA

The residual left after thermal degradation process was 60.1 % and 54% for CBA 50 % and 25 % respectiely. The lower amount of residual left in second case due to the higher percentageage of biomasss.Biomass has conataing more volaoitle and carbon compound then CBA. The weight loss in different time periods is shown in Fig. 5.

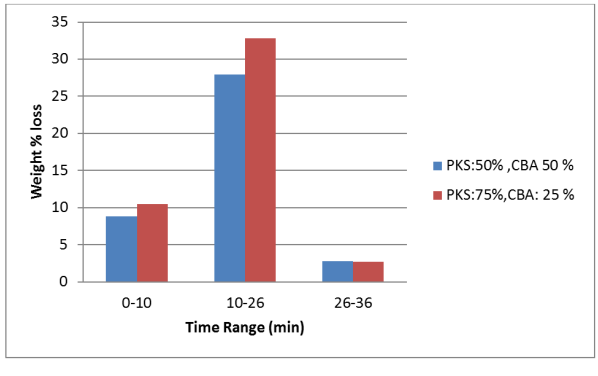


Figure 5 : Comparison of weight loss % of 50% CBA and 25 % CBA

4. Conclusions

The thermal degradation of PKS was performed by blended with 50 and 25 % of CBA in a thermo gravimetric analyser (TGA) to understand the effect of CBA in thermal decomposition of CBA. From study, It was found the weight loss % 10.5 and 32.81 % at temperature region 0-260 and 250-650 ^{o}C for CBA 25 %. For 50 CBA the weight loss % was 8.8 and 27.6 % at s same temperature region. It has been concluded the weight loss was getting lower by adding CBA. On the other hand at temperature 650 ^{o}C the CBA 50 % shows more weight loss about 2.81 than CBA 25 % 2.72.About 60.5 and %4.1 residual was left for 50 and 25 % CBA respectively. The decomposition of hemicelluloses and cellulose has been take place above 270 and 370-400 ^{o}C respectively indicated by DTG profile. 300-400 ^{o}C temperature region was more effective for weight loss % and DTG rate. It is conclude that CBA has effect in thermal decomposition of PKS and optimized values should be determined before using in gasification process.

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Figure captions

1. Fig. 1 Biomass waste distribution in Malaysia
2. Fig. 2 Weight loss % Vs Time for (A) 50% CBA and (B) 25 % CBA
3. Fig. 3 Weight loss % Vs Temperature for A 50% CBA and B 25 % CBA
4. Fig. 4 DTG % Vs Temperature for A 50% CBA and B 25 % CBA
5. Fig. 5 Comparison of weight loss % of 50% CBA and 25 % CBA