Thermal and kinetic analysis of biomass fuel (powders) by differential thermal gravimetric analysis (TGA/DTG/DTA)

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Abstract

The kinetics of the thermal decomposition of the agriculture residues were evaluated using a thermo-gravimetric analyser under non-isothermal conditions. The thermal behaviour and pyrolysis of two types of biomass i.e. pearl millet cob and eucalyptus by using TGA from ambient to 1000°C. Three different heating rates (10, 15, and 20°C/min) were taken for the thermogravimetric analysis. This study provides a basic insight into the Pearl Millet Cob pyrolysis, which can benefit our current work in developing advanced thermal processes for high-yield producer gas production from pearl millet cob waste.

Keywords: Thermogravimetric analysis, Derivative thermal analysis, Differential thermogravimetric analysis, Activation energy.

1. Introduction

Global warming, and detrimental impact of fossils on the environment are pressing the whole world to move to other alternative sources of energy (White et al. 2011). The benefits of biomass, the third largest energy resource in the world, are its abundance, renewability and its property of balancing carbon in nature (McKendry, 2002; Vamvuka et al. 2003; Ragauskas et al. 2006). The devolatilization parameters of biomass are determined by its thermal behaviour (Caballero et al. 1997;). As a thermal analysis technique, thermogravimetric analysis (TGA) is now being extensively employed to study the thermal behaviour of coal, biomass, polymers, etc. (Perry and Chilton, 1973; Raveendran et al. 1995). Thermochemical methods such as gasification, liquefaction, pyrolysis, torrification and combustion, are usually preferred over biochemical methods for energy production (Sayed and Mostafa, 2014). The differential thermogravimetric analysis (DTG) curve is obtained from TGA experiment of a sample of biomass. In the derivative thermal analysis (DTA) curves heating rate affected the heat absorption and heat release characteristics of the biomass. The current work explores the thermal degradation characteristics of pearl millet cob and eucalyptus wood and their kinetics.

2. Material and Methodology

Biomass samples for this investigation were grinded in a hammermill. The proximate analysis and ultimate analysis are shown in Table 1. Volatile content and calorific value indicate their potential as energy feedstocks. Thermal degradations, namely TGA and DTA, has been carried out at three heating rate 10, 15 and 20°C min^{-1}, from ambient temperature to 1000 ◦C in inert atmosphere. Kinetic analysis for obtaining activation energy has been performed using KAS method.

3. Results and Discussion

3.1 Thermogravımetric analysıs

The TGA curves of three heating rates of 10, 15, 20 °C/min are shown in Figure 1 and 2. Drift of the thermograph towards higher temperatures with increasing heating rates can be noted for both the biomass samples from these figures. The degradation of biomass occurs in three stages. The mass loss in the initial stage (up to 100 °C) may be attributed to the loss of moisture present in biomass samples. In the next stage between temperatures 100 - 350°C, the second mass loss can be attributed to volatile matter. In stage-III, the third mass loss occurs between 350°C and 610°C and may be occurring due to fixed carbon and Here for in case of eucalyptus first mass loss may be due to moisture up to 152°C, second due to volatiles of temperature rang was 152-500°C and

Table 1. Thermochemical characteristics of the biomass

Biomass	Proximate analysis (wt%)				Ultimate analysis (wt% dry basis)				Calorific value(MJ kg^{-1})	
	Moisture	Volatile matter	Fixed carbon	Ash	C	H	N	O	LHV	HHV
Eucalyptus	6.5	69.5	22.7	1.3	46.61	6.33	0.033	47	19	20.4
Pearl millet cob	10	72.5	4.4	13.1	45	6.39	0.772	47.81	15.6	17.02

the third due to fixed carbon in the temperature range between 500-700°C.

3.2 DTG and componential analysis

A DTG curve may be an indicator of componential decomposition characteristics of biomass (Figures 1 and 2). The smaller peak of devolatization represents the decomposition of hemicellulose taking place at a lower temperature. The degradation of cellulose is represented by the larger peak in Figure1 and 2 and the last peak is present due to degradation of more complex components. Lignin was decomposed throughout the entire temperature range. In the pearl millet cob first peak for devolatilization occurred in the range of 227-256°C, second peak at temperature range between 256-367°C and third degradation at 367-575°C, while in case of eucalyptus the DTG peaks were in the range of 271-311° C for the first, between 311-380°C for the second and in the range of 380-510°C for the third peak.

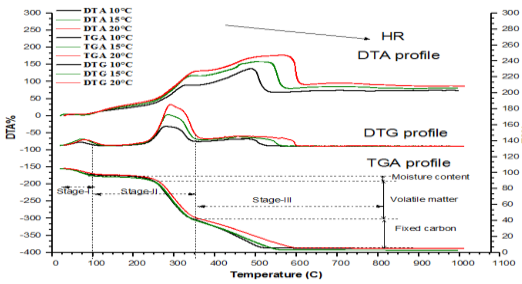

Figure 1. Thermal degradation of pearl millet cob

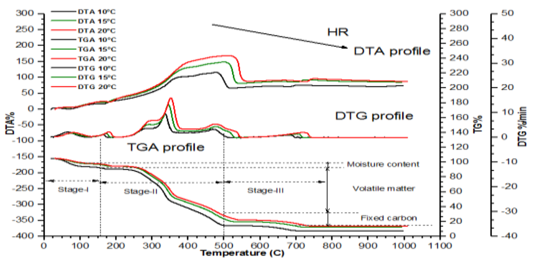

Figure 2. Thermal degradation of eucalyptus wood

3.3 Dıfferentıal thermal analysıs

The characteristics pertaining to exothermicity (heat release) and endothermicity (heat absorption) can be seen during degradation of biomass from DTA curves as shown
in Figure 1 and 2. As clearly visible, these characteristics are affected by heating rate. The first and second peak in DTA curve may be formed due to the oxidation of volatiles and char respectively.

3.4.Kinetics parameter

The apparent activation energies at various conversions for eucalyptus, pearl millet cob and corncob are shown in Fig 3. The disparity of activation energies as a function of the mass percentage of eucalyptus, pearl millet cob are also shown in this figure 3. Average activation energy for eucalyptus was found 70.84 kJ/mol for pearl millet cob 101.93 kJ/mol. Pearl millet cob hence is apparently having higher thermochemical reactivity than eucalyptus.

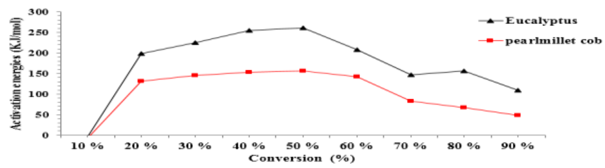

Figure3. Activation energy by KAS method

4. Conclusion

Thermal degradation of eucalyptus and pearl millet cob was performed and TGA, DTG and DTA studies were carried out. Three different stages of degradation in TGA curve exist for moisture, volatile matter and fixed carbon. In DTG curve various peaks occurring due to hemicellulose, cellulose and lignin are identified. While hemicellulose and cellulose yielded apparent peaks, lignin degrades throughout. The kinetic analysis indicated higher thermochemical reactivity of pearl millet cob as compared to eucalyptus.

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