Thermal Degradation Characteristics of Blends of Tanzanian Bituminous Coal and Coffee Husks

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ABSTRACT
Coal combustion is associated with technical problems such as poor fuel ignition, flame instability, low efficiency, pollutant emissions, and poor char burn out. On the other hand biomass fuel is considered environmentally friendly due to the following; there is no net increase in CO_2 from burning biomass fuel since they consume CO_2 from the atmosphere during growth and release during combustion. Therefore, blending coal with biomass fuels such as coffee husks can reduce fossil coal CO_2 emission. Most biomass fuels have very little or no sulphur and therefore net SO_2 emissions can also be reduced. Interaction between the blend components can positively modify the degradation characteristics as compared to pure coal. In this paper, thermal degradation characteristics of blends of bituminous coal and coffee husks material are presented. The thermal degradation characteristics of the blends were obtained using thermogravimetric analyzer (TGA) and Differential Scanning Calorimetry (DSC). Thermal characteristics and the reactivity of the blends in different degradation stages are discussed. The findings reveal that bituminous coal and coffee husks blend is able to enhance the thermal degradation of the coal through the secondary pyrolysis reactions.

Keywords: Clean Fuels, Coffee Husks, Differential Scanning Calorimetry (DSC), Gasification, Tanzania, Thermogravimetric (TG)

1.0 INTRODUCTION

Rapid increase consumption of fossil fuels and concern over the environmental pollution problems promote clean energy utilization. Recently, interests in coal blends with other resources such as biomass waste have been growing as alternative feedstock for energy production via combustion and gasification technologies. Coal and different types of biomass blends like urban, forest and industrial solid waste, have been researched as being clean and economic energy alternatives allowing the substitution of traditional fossil fuel. This brings a possibility of mitigating both the environmental impact brought by fossil coal use and simultaneously resolving waste management. Coal blend reduces polluting gases such as nitrogen oxides and sulphur (Romero, 2002), and improving combustion efficiency at the same time (Gayana *et al*., 2004).

Biomass waste is the most common fuel used in blending with coal. Since biomass is considered as CO_2 neutral with low contents of sulfur, it is becoming an important alternative renewable energy resource. Biomass and coal, however, have different chemical and physical properties, such as volatile matter, ash and composition, density, and calorific value. These differences in the properties lead to different reactivity and thermal characteristics during combustion. Combustion of coal with biomass is presently being considered as an effective method to reduce global CO_2 emission and some important pollutants such as NO_x, SO_x, (Chao *et al*., 2008). However, studies on the fundamental parameters to investigate the behavior of biomass and coal blend under high temperature are relatively sparse. Thermal degradation analysis under high temperature can be considered as an independent process to produce various chemical reactions and fuels. It can also be considered as the initial step in all the thermal conversion processes including combustion and gasification of carbonaceous materials. Thermochemical reactivity and volatiles content is poor for coal. Since these are responsible for facilitating the thermal conversion and fuel upgrading leads to the poor environmental performance of the coal. Therefore, it is desirable to blend biomass and coal for sustainable utilization of coal and to minimize the impact on the environment.

In this paper, thermal behavior during thermal degradation of coal and biomass blend was determined in a thermogravimetric analyzer (TGA). The emanating results may be utilized to predict the reactivity behavior of biomass and coal blend for proper design of thermal conversion system.

2.0 METHODS

The material selected for this study was bituminous coal and coffee husk whose proximate and ultimate analysis is given in Table 1. After milling the individual fuels to an average of 100µm in diameter the sample were dried at 105°C for two hours in VECSTAR 174799 furnace model F/L. Blends of bituminous coal with coffee husk were prepared by mixing to ratios of 50:50, 70:30, 90:10 (coal:husks). The blends of bituminous coal with coffee husks were subjected to a thermogravimetric analyzer for analysis. The thermal degradation characteristics of these samples were measured by use of TGA type NETZSCH STA 409 PC Luxx. The samples were heated at constant rate of 10°C/min in nitrogen atmosphere from ambient to 1000°C.

Table 1: Proximate and ultimate analysis (% dry basis)

Proximate Analysis	**Coffee Husks**	Coal
Ash	2.50	53.470
VM	83.20	18.848
FC	14.30	27.686
Ultimate Analysis		
C	49.40	85.000
H	6.10	5.300
N	0.81	0.507
O	41.20	5.270
S	0.07	0.692
CV(MJ/kg)	18.34	33.280

3.0 RESULTS AND DISCUSSION

Figure 1 shows that the reactivity of the blend increases with increasing coffee husks content. Since bituminous coal volatile matter content is less compared to the coffee husks, blending with the husks is positively influencing the combustion characteristics of the blend.

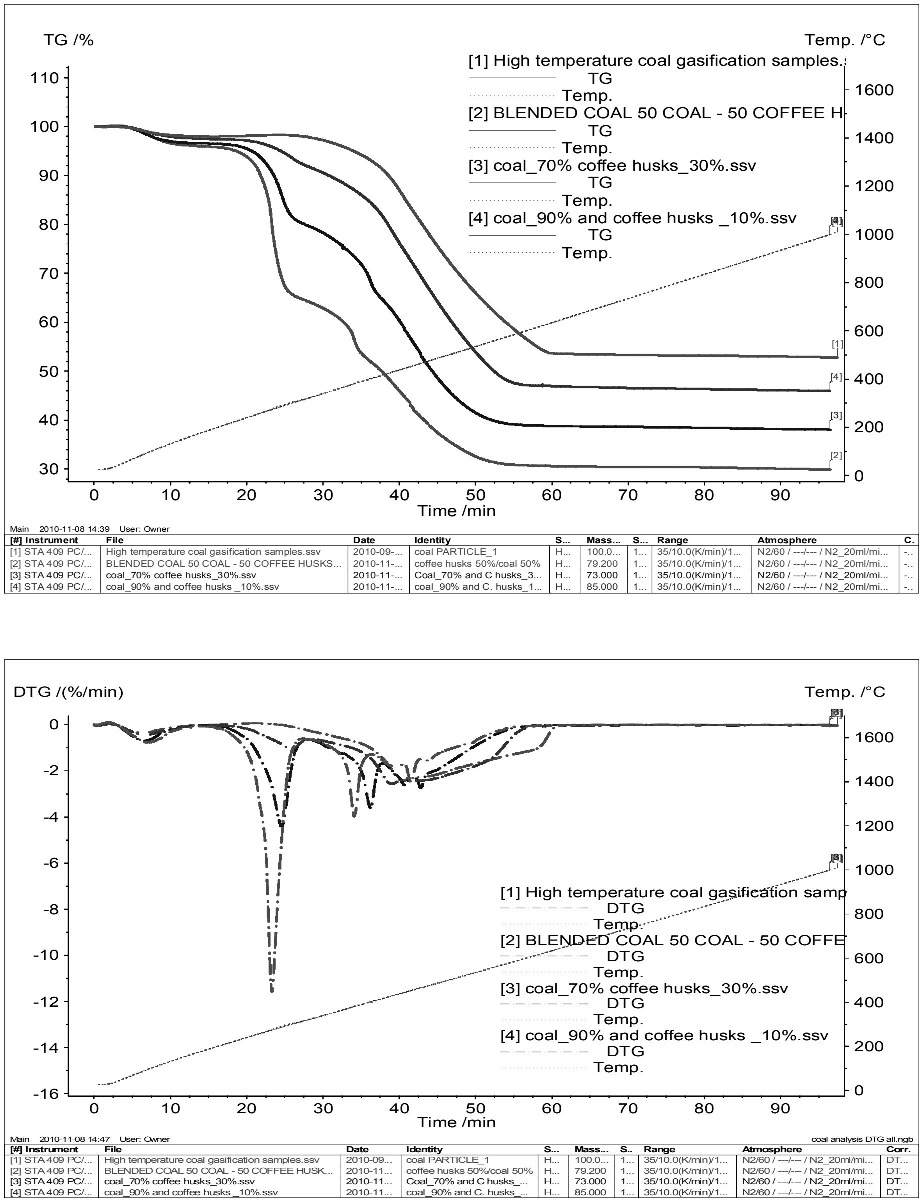

Figure 1: TG and DTG for 100% coal; 50:50; 70:30; 90:10; coal/coffee husks

Thermal degradation of coal starts at above 400°C and continues as temperature increases to around 600°C. On the other hand, thermal degradation of coffee husks starts below 200°C. The total volatiles produced are approximately 80 wt.% of the initial sample weight on dry basis. It is observed that more than 85% of the total volatile matter is evolved within the temperature range of 200–400°C. The difference in devolatilization rates between coffee and bituminous coal is mainly caused by their structural properties. Cellulose and lignin bonds in the macromolecular structure of husks/biomass are relatively weak. Consequently, the bonds are broken easily in the low temperature region. The backbone of coal structure is, however, made of dense polycyclic aromatic hydrocarbons whose stability (high bond energy) makes them more resistant to thermal decomposition (Sadhukhan *et al.*, 2008)

The first derivative TG (DTG) curve peak is lower as the content of coffee husks is lowered and this indicates that the blend becomes less reactive. This is because the first peak is largely contributed by the hemicellulose present in the coffee husks. Furthermore, less char is obtained from higher coffee husks blends compared to the lower blend counterparts. It can be inferred that the presence of coffee husks promotes the production of volatiles in coal pyrolysis. This result was also observed during the pyrolysis of biomass with different ranking coals (Haykiri-Acma and Yaman, 2010). It has been reported previously that more volatiles can be produced from coal pyrolysis by adding hydrogen donors from other organic resources (Straka *et al*., 2004; Ishaq *et al*., 2006; Sharypov *et al*., 2007).

The relatively high content of H_2 in the biomass structure is therefore an important H_2 donor during pyrolysis of the coal blends. Hydrogen may prevent recombination and cross-linking reactions of free radicals that increase char formation (Zhang *et al*., 2007; Sonobe *et al*., 2008). Consequently, more volatiles are produced from thermal decomposition of the blend than that from the individual thermal decomposition of coal and coffee. From DSC analysis of coffee husks pyrolysis, definite endothermic and exothermic peaks can be observed at 380 and 420°C, respectively. The first endothermic peak and the second exothermic peak correspond to the decomposition of hemicellulose and lignin, respectively (Ishaq *et al*., 2006). In the case of thermal decomposition of coffee and coal blend, a similar endothermic peak is observed at around 380°C, but exothermic peak is diminished.

4.0 CONCLUSION

i) Blends of coffee husks and coal in TGA produce more volatiles highly pronounced above 400°C. Under this condition the yields of the major pyrolysis products (e.g. gas, tar, and char) are high from coal blended with coffee husks.
ii) The reactivity of coal/coffee husks blend is higher for the high coffee husks content in the blend.

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Yield and Chemical Characteristics of Charcoal Produced by TLUD-ND Gasifier Cookstove Using Eucalyptus Wood as Feedstock

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ABSTRACT
A Top-Lit UpDraft Natural Draft (TLUD-ND) gasifier cookstove primarily pyrolyses biomass feedstock and then burns combustible gases separately to provide heat for cooking while giving out charcoal as a byproduct. In this study, the charcoal produced from water boiling test (WBT) conducted on the stove was analyzed for its suitability for domestic use. Three fuel sample sizes were used and the charcoal produced was then characterized by proximate analysis to observe the effect of feedstock size on yield and characteristics of the charcoal produced. The results showed a mean charcoal yield of 18 % with slight variation over the range of considered feedstock size. The produced charcoal had average proximate analysis of; fixed carbon (FC) = 86.2%, volatile matter (VM) = 12% and Ash = 1.8%. When this is compared with traditional kilns having typical yield not exceeding 20%, it has been shown that charcoal from TLUD-ND realizes slightly higher energy recovery due to high fixed carbon content. Nevertheless, the low volatile matter content of the charcoal makes it friable making handling difficult. Moreover, the energy transferred to cooking pot was regarded as net additional fuel saving attained by the stove compared to traditional charcoal kilns.

Keywords: Charcoal yield, Energy recovery, Gasifier stove, Proximate analysis, Pyrolysis

1.1 INTRODUCTION
Traditional methods of charcoal production in developing countries realize gravimetric yield of 20% or less, and modern industrial technology offers yields of 25-37% (Antal *et al.*, 1996). Improved charcoal stoves made from pottery with good insulation are capable of delivering up to 30% efficiency. When these efficiencies of charcoal production and use are combined taking the difference in their heating values into consideration, cooking with charcoal realizes energy transfer of 10% or less to the end-use. Thus, even given the high efficiencies of charcoal stove, the use of charcoal for cooking is always less energy efficient than cooking with wood since a well managed open fire has an efficiency of 10-15% (Charles and Essel, 2000). The reason is that about 30% energy recovery corresponding to the 20% gravimetric yield implies large energy loss (over 70%) due to the volatiles liberated in the form of smoke in the kiln site while making charcoal (Quaak *et al.*, 1999). Conversely, TLUD-ND gasifier cookstove first utilizes the volatile matter for cooking and then gives charcoal as an output; ideally allowing 100% availability of the primary energy content of the feedstock for cooking. Hence, the main objective of this paper is to assess the competence of TLUD-ND gasifier cookstove as an alternative charcoal making apparatus in saving fuelwood.

1.2 Equipment and Material

1.2.1 TLUD-ND Gasifier Cookstove
TLUD-ND gasifier cookstove is a newly introduced alternative cooking stove developed to provide cleaner and better controlled gas for cooking (Reed and Larson, 1996). Once the fuel gets lit on top, the stove first pyrolyses feedstock with the help of limited primary air supply; thereby generating combustible gas which is later combusted when mixed with secondary air to