Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. VII, 2018
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THERMAL PROPERTIES OF PELLETS MADE OF PEACH PIT AND LIGNITE COAL DUST

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Abstract

Densification of biomass materials can be achieved through pelletization technology, which can be used to produce useful, high value added, and salable pellets. In this study, pellets were made using peach pit (PP) with Lignite Coal Dust - coal powder (CP) at specific ratios. Pelletization was performed by a pelletizing machine having flat die and roller with a capacity of 50-60 kg/h. The pellet die had an inlet hole diameter of 11 mm, an outlet hole diameter of 7 mm and a die height of 25 mm. The pellets were the mixture of PP and CP: 100% CP, 90%CP+10%PP, 75%CP+25%PP, 50%CP+50%PP, 25%CP+75%PP, 10%CP+90%PP, and 100%PP as dry weight basis. Proximate analyses and higher heating values of the pellets were determined. Thermogravimetric and differential thermogravimetric analysis were performed. The results were presented in the study.

Key words: *peach pit, lignite coal powder, pelletization, thermogravimetric analysis.*

INTRODUCTION

The energy requirement of the world is increasing due to the developing technology and the increasing human population. However, energy resources, especially oil, is gradually declining. In addition to the problem of diminishing energy resources, the greenhouse gases generated due to the burning of hydrocarbon resources make the world climate warmer. Alternatively, clean and renewable energy sources have become important due to factors such as decreasing energy sources, increasing energy demand and negative effects of greenhouse gases. Agricultural and other biomass wastes are an important resource for meeting energy needs, especially in developing countries, and in the majority of these countries, there is a large amount of waste existing every year. Since agricultural wastes are of low density and high moisture content, direct burning in houses and industrial areas is not very effective, direct use of these wastes causes transport, storage and processing problems and most importantly causes environmental pollution. One of the ways in which agricultural and other biomass waste can be used effectively is by their pelletization. Biomass fuel quality can be improved by pelletization process for example, increase in bulk density, uniformed shape and size (Li et al., 2012; Gil et al., 2010; Obernberger and Thek, 2004). Therefore, pellets can be utilized for many combustion applications such as grate furnace and gasification in fluidized bed furnace for residential and industrial operations. Although many studies concerned mechanical durability of biomass pellets while combustion behavior of the pellets has been seldom reported (Gil et al., 2010; Obernberger and Thek, 2004). This study aimed to determine some thermal properties of pellets made of peach pit (PP) and lignite coal dust-cool powder (CP). The results of this study could help the designer/decision makers on not only development of biomass utilization processes but also usage of these fuels with together for power generation.

MATERIALS AND METHODS

This study involved CP and PP. The PP was received from a company in Isparta province. CP was purchased from a coal retailer in Isparta. In the study, the seven different pellets were prepared using mixing ratios based on dry weight basis of the materials used for pellet production.

The pellets were named based on the proportions of raw materials added to the blend as (%) CP- (%) PP. For example, „10CP-90PP" means „(10%) CP-(90%) PP" as dry weight basis. 100PP and 100CP are the pellets where only raw material themselves were used for pellet production. Therefore, the properties of the pellets can be considered as those of raw materials.

The raw materials were dried at a constant temperature of 35˚C for 72 h. Pelletization was performed by a pelletizing machine having flat die and roller with a capacity of 50-60 kg/h. The pellet die has an inlet hole diameter of 11 mm, an outlet hole diameter of 7 mm and a die height of 25 mm. Then, the pellets were dried at the room condition.

The moisture content (MC) of the pellets was determined according to ASTM D 3173. The ash content (AC) of the pellets was determined according to the ISO 1171 standard. The volatile matter (VM) of the pellets was determined according to the ISO 562 standard. The fixed carbon (FC) of the pellets was obtained from the equation (ASTM D3172). Higher heating value (HHV) was calculated according to the equation HHV (MJ/kg) = 0.312 FC + 0.1534 VM, FC and VM were the percent of fixed carbon and volatile matter of the fuel, respectively (Baley, 1984).

Thermogravimetric analysis (TG) as well as derivative thermogravimetry (DTG) applied to investigate the combustion characteristics was performed by a thermogravimetric analyzer (Perkin Elmer Diamond TG/DTA model). All combustion experiments were conducted at atmospheric pressure, using temperature range from 25 to 900°C with a heating rate of 10°C/min and an air flux of 20 ml/min with N_2 gas.

RESULTS AND DISCUSSIONS

The proximate analyses of pellets are presented in Table 1. 100PP or PP had the lowest ash content (1.76%), while the 100CP or CP had the highest ash content. The addition of PP to the blend relatively decreased ash content of pellets. For example, addition of 10% PP to the blend (90CP-10PP) reduced the ash content of pellets from 18.95% to 18.58%. Reduced ash content indicates the improvement of fuel quality. Furthermore, increased fixed carbon content and elevated HHV indicate enhanced fuel quality (Liu et al., 2014). 100CP pellets had the highest fixed carbon content and HHV whereas 100PP had the opposite. Addition of PP to the blend reduced fixed carbon and HHV of the pellets. The fixed carbon ratios in all combustible carbon were 41.13% and 10.02% for 100CP and 100PP, respectively. For example, the addition of 10 and 25% PP to the blend (90CP-10PP and 75CP-25PP) reduced fixed carbon from 41.13% to 34.4% and 32.06%, respectively. As a result of the decreased fixed carbon ratios, the HHVs also decreased from 18.21 MJ/kg to 17.16 and 17.11 MJ/kg, respectively. The more PP in the blend, the less fixed carbon content and HHV. Therefore, the addition of PP should be optimized based on ash content, fixed carbon and HHV of the pellets.

Table 1. Proximate analysis and higher heating values of the pellets

Pellets	Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)	HHV (MJ/kg)
100PP	8.72±0.51	1.76±0.35	79.49±0.25	10.02±0.6	15.32±0.15
10CP-90PP	8.24±0.29	3.02±0.49	73.83±0.24	14.91±0.72	15.98±0.19
25CP-75PP	7.92±0.66	7.31±0.66	64.01±1.27	20.77±1.93	16.3±0.41
50CP-50PP	6.80±0.75	11.34±0.32	57.37±0.25	24.5±0.06	16.44±0.06
75CP-25PP	5.71±0.15	15.9±0.31	46.32±0.11	32.06±0.20	17.11±0.08
90CP-10PP	5.10±0.43	18.58±0.81	41.91±0.92	34.4±0.13	17.16±0.1
100CP	4.88±0.21	18.95±0.23	35.02±0.76	41.13±0.53	18.21±0.05

In order to evaluate the effect of the amount and the type of raw material (CP and PP) on the combustion characteristics, the pellets were subjected to thermogravimetric analysis. The TG and DTG profiles of the pellets as a function of temperature for seven different pellets are shown in Figure 1a, b, c, d, e, f, and g with the temperature range of 20-900°C. TG curves from all pellets had four typical combustion stages, representing the dewatering phase, the combustion of volatile matter, the combustion of fixed carbon and burnout (Jiang et al., 2014). While all the TG profiles for all the pellets are given in Figure 2a, all the DTG profiles are given in Figure 2b for comparison purpose. The characteristic combustion parameters were defined as T_{i1} and T_{f1}: initial and final combustion temperature (the primary devolatilization process (°C) (Vamvuka et al., 2003), T_{max1}: temperature at maximum weight loss rate (the primary devolatilization process) (°C), T_{i2} and T_{f2}: initial and final combustion temperature (°C), T_{max2}: temperature at maximum weight loss rate (°C) and r: maximum weight loss rate (%/min) corresponding the primary devolatilization process. The summary of characteristic combustion parameters for seven different pellets are given in Table 2.

It can be observed that the thermal decomposition of pellets starts at approximately T_{i1}, followed by a major loss of weight, where the main devolatilization occurs, and the thermal decomposition is essentially completed by T_{f1} (Figure 1 a, b, c and f) (Vamvuka et al., 2003). However, the combustion of 100CP, 90CP-10PP, and 75CP-25PP pellets occurred in two separated temperature ranges (163.45°C-379.99°C and 379.99°C-578.64°C), (161.06°C-412.88°C and 412.88°C-555.19°C), and 158.06°C-412.88°C and 412.88°C-552.90°C), respectively, caused by the big difference of the reactivities among different constituents (Figure 1d, e and g).

It can be concluded that increasing the ratio of PP in the blend led to decrease in T_{i1} and T_{max1} parameters. Furthermore, 50CP-50PP, 25CP-75PP, 10CP-90PP and 100PP had lower T_{i1} and T_{max1} than those of the rest of pellets (Table 2). The results are consistent with those reported by (Vamvuka et al. 2003).

The maximum weight loss rates (r) drastically increased with increasing PP in the blend. For example, addition of 10 % PP to the blend (from 100PP to 90CP-10PP) r increased from 0.7 to 1.34%/min (91.43%). There was no difference detected in terms of r between 90CP-10PP and 25CP-75PP. Adding more PP to the blend caused the dramatic increase in r. For example, 25CP-75PP and 10CP-90PP had the r values of 3.21 and 4.52, respectively. This indicates that there should be limit for the addition of biomass to coal blend. Likewise, Vamvuka et al. (2003) stated that 10% and 20 % biomass addition to coal/biomass blend are typical of co firing applications used in the European industry. Furthermore, Liu et al. (2014) and Obernberger and Thek (2004) stated that the increased final temperatures and the decreased maximum weight loss rates indicated that the pellets are combusted in a more moderate way. The continuous and elevated combustion temperature ranges coupled with significantly increased final temperatures suggests that the higher thermal efficiency can be achieved for combustion. Vamvuka et al. (2003) stated that the DTG peak height is directly proportional to the reactivity, while the temperature corresponding to peak height inversely proportional to the reactivity. Figure 2b shows DTG of all pellets indicating that pellets having high amount of PP in the blend for example, 100PP, 10CP-90PP, 25CP-75PP, and 50CP-50PP are more reactive than those having high amount of CP in the blend. This combustion behavior could be due to the fact that PP had higher volatile content than CP (Vamvuka et al. 2003; Liu et al., 2014; Jiang et al., 2014).

CP itself yielded 62.82% of residues after combustion (Table 2). The similar result was reported by Vamvuka et al. (2003). Addition of PP to the CP/PP blend reduced the percentage of residues. For example addition of 10% of PP to the blend reduced the residue from 62.82% to 53.70%.

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

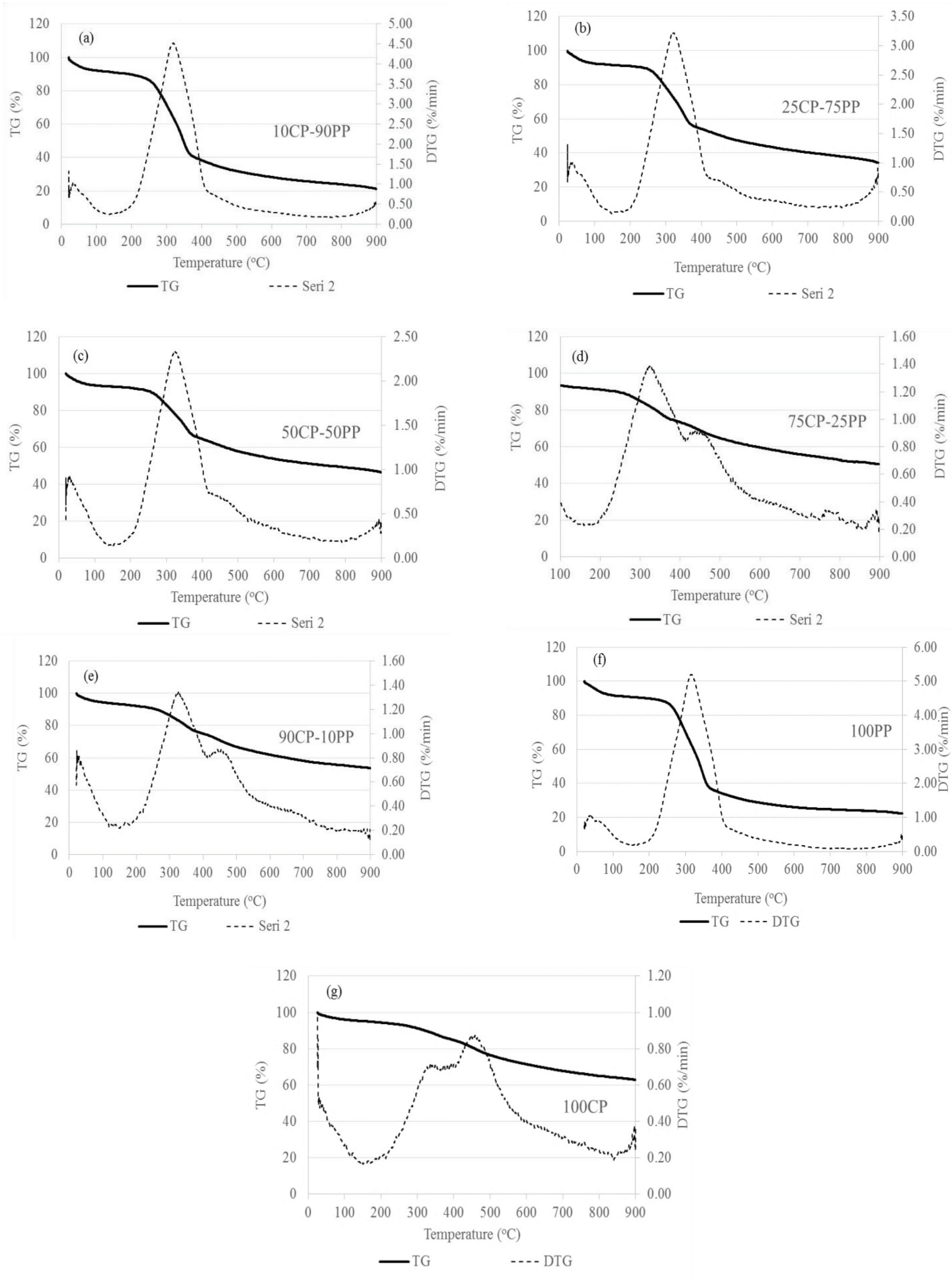

Figure 1. TG and DTG profiles for pellets

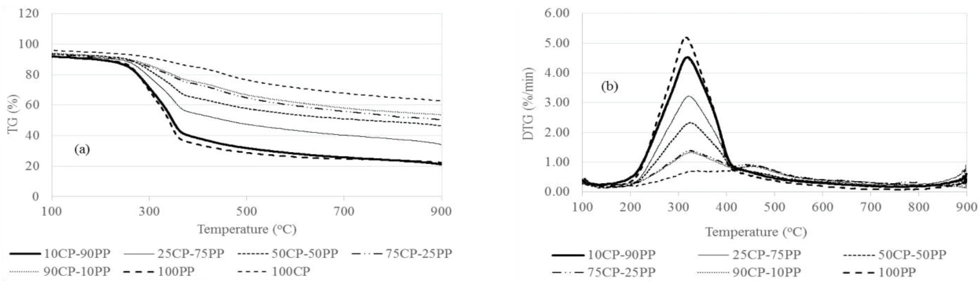

Figure 2. TG (a) and DTG (b) profiles as a function temperature for all pellets

Table 2. The characteristic combustion parameters for the pellets

Pellets	T_{i1} (°C)	T_{max1} (°C)	T_{f1} (°C)	T_{i2} (°C)	T_{max2} (°C)	T_{f2} (°C)	r (%/min)	Residue (%)
100CP	163.45	341.62	379.99	379.99	458.36	578.64	0.70	62.82
90CP-10PP	161.06	327.00	412.88	412.88	451.97	555.19	1.34	53.70
75CP-25PP	158.06	327.00	412.88	412.88	451.97	552.90	1.34	50.45
50CP-50PP	154.59	324.46	484.86	-	-	-	2.33	46.44
25CP-75PP	153.35	323.08	450.47	-	-	-	3.21	34.12
10CP-90PP	148.65	319.81	423.75	-	-	-	4.52	21.14
100PP	154.85	313.76	439.57	-	-	-	5.19	22.22

CONCLUSION

Seven different pellets were prepared using peach pit and lignite coal dust using pelletization machine.

Proximate analysis and higher heating values were performed.

Thermogravimetric analysis and derivative thermogravimetry were applied using thermogravimetric analyzer.

The results on proximate analysis and higher heating values of pellets showed that the more peach pit in the blend, the less fixed carbon content and HHV are.

Therefore, the addition of peach pit to pellet blend should be optimized based on ash content, fixed carbon and HHV of the pellets.

It was concluded that increasing the ratio of peach pit in the blend led to decrease in T_{i1} and T_{max1} parameters.

The maximum weight loss rates (r) of pellets drastically increased with increasing PP in blend. Addition of peach pit to the blend reduced the percentage of residues after combustion.

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