EVALUATION OF THERMOCHEMICAL AND KINETIC CHARACTERISATION OF LIGNITE AND MUNICIPAL SOLID WASTE AND THEIR BLENDS FOR SUSTAINABLE AND CLEAN CONVERSION UNDER TGA

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With the expansion in generation of municipal solid waste (MSW) due to population growth, and also increase the demand of clean energy production, and the curb of landfilling of MSW, it has established the need of our society to use MSW with the available lignite under-the-vision of waste-to-energy (WtE). WtE technique is an environment-friendly way for disposing of MSW into the useful way globally. The thermal characteristics of MSW with lignite and their blends were investigated to analyze thermal stability. Blends of 10%, 20%, 30% and 50% of MSW with lignite were prepared and tested in thermogravimetric analyzer from ambient to 1000 °C under heating-rate 10°C/min. This study revealed that steep in weight-loss profiles in TG curves was reduced as MSW contents increased. It was observed, MSW proportions in blends significantly affect the combustion profiles and associated parameters like ignition temperature, weight-loss and activation energy. The blends showed combustion properties of MSW and lignite as maximum weight-loss occurred between the individual fuels. Moreover, results indicated that with low proportion of MSW as 10% didn't significantly affect the combustion behavior and properties. While blend 30% shows the more thermal stability than other samples. Thermal profiles of all blended samples occurred in between of the parent samples. Results obtained from experiment help to predict co-combustion thermal behavior of MSW and lignite in existing facilities to generate clean-energy in sustainable way from commercial power plants. The kinetic parameters obtained by Horowitz-Metzger method showed improvement in ignition performance and find the difference between blends.

***Keywords**: Municipal solid waste, Lignite, Waste to energy, Co-combustion, Thermogravimetric analysis.*

1 Introduction

Quite recently, many countries are facing issues related to solid waste management (SWM) as the waste generation trend is increasing day by day. The issues related to the disposal of MSW are increasing all over the world due to urbanization, population growth and industrialization [1] affecting health, environment and safety [2]. Its contribution to global warming and climate change caused by non-CO_2 greenhouse gases has placed MSW sector to fourth position by producing 5.5–6.4 % towards global methane (550 T_g) emissions annually [3]. Currently 1.5 billion tonnes of MSW are being generated globally at different levels and is expected to increase to 2.2 billion tonnes per year by 2025 [4]. The current methods of solid waste demolition in landfills, incinerators and open dumps are affecting environment by causing pollution [5]. In order to raise the proportion of clean energy and reduce greenhouse gas emissions, along with environmental awareness to keep the environment safe from pollutants and unsustainable technologies such as landfilling, treatment of residual waste with various WtE techniques is a feasible way for waste disposal and energy production.

MSW is considered as one of the renewable energy resource United State departments of energy and environmental protection agency [6]. Waste generation rate in all municipal controlled area in major cities of Pakistan varies from 1.896 kg/house/day to 4.29 kg/house/day [7]. Quantity along with composition of solid waste in Lahore, Pakistan by weight % is shown in Figure 1.

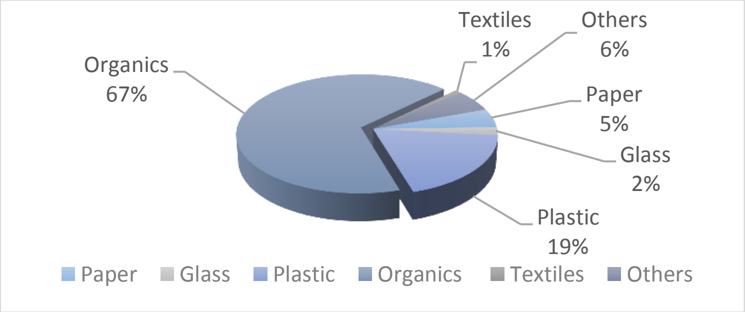

Figure 1: Composition of MSW [7,8]

The wastes that must be recovered in order to create a new useful product are plastic waste, paper and cardboard waste, glass and metal refuse, which can be repurposed to create new products [9,10]. Energy recovery from garbage can only be applied to waste that cannot be recycled. WtE technology can convert these non-recyclable wastes into heat energy, power, or some combustibles. This component of SWM not only recovers energy from waste but also handles the issue of waste disposal [11,12]. Energy recovery from waste helps to lower the proportion of fossil fuels in the energy mix and the trash burden on landfills, resulting in landfills taking up less area [13]. Landfills are designated sites for the disposal of trash [14]. They are generally found on the fringes of big cities and serve as the final destination for MSW. Unrestrained exposed dumping sites pose a serious threat to the environment, particularly to soil, groundwater, and, most importantly, human health [15].

The approach for defining refused derived fuel (RDF) in other countries is mostly determined by the materials used to make it and the treatment methods that can be used prior to combustion under legal jurisdiction [16]. In general, refuse is a term used to characterize solid and commercial garbage. Typically, RDF refers to high calorific value waste originating from MSW, industrially processed waste, and commercial waste [17]. MSW has numerous sub-derivatives, including plastic and paper waste, packaging waste, processed waste, and energy recovered waste (material having energy but non-recyclable). These sorts of garbage are distinguished either by the primary waste component form from which they are composed or by the manner in which they are treated and processed, or they are referred to as rejected recyclables. Producing RDF from MSW reduces reliance on fossil fuels while also assisting in the reduction of landfill space [18]. When it comes to meeting the requirement of recycling and treatment of biodegradable waste in accordance with the stipulated landfill directive 1999 [19], RDF plays a significant role in SWM. Separating decomposable waste from MSW and using it to make RDF minimizes the amount of land required for waste landfilling.

Coal is considered among one of the efficient and low-cost energy sources used for electricity generation in all over the world. Even concerns about climate change could not reduce global reliance on coal for energy generation as its consumption surged to 7547 MT in 2017 with 3.1% increase [12]. Contrary, coal-based energy generation is providing much needed push for progress in economic growth and development in most of the developing countries. Currently high-quality coal is imported from other countries to fill demand and supply gap in Pakistan. Approximately 186 billion tonnes of coal reserves have been discovered in Pakistan but its production for energy purposes has recorded to only 4.14 million tonnes [15].

Mixing of coal with waste extracted fuel is a viable way for effective waste management, reduction in environmental pollution and faster usage of MSW in existing facility. MSW has higher moisture and volatile matter but lower carbon content as compared with coal, mixing of MSW with coal will affect combustion profiles along with unit efficiencies [20]. The combustion equipment needs to be designed for predetermined blending of both fuels for proper combustion which will greatly depend upon the homogeneity of the blended fuels. World is taking interest in creating effective thermal upgraded techniques to provide eco-friendly solutions that will help to meet energy demands by using waste derived fuels [21].

With the improvement in living standards and human civilization, the quality of MSW is getting better with more combustible components in it while promoting the process of recycling of plastics and metals. There have been a lot of research reports on co-combustion of coal with MSW, paper mill sludge, waste tyres etc. so far [19].

Some research suggested that combustion of MSW with coal can improve the combustion profiles and decomposition behaviour of individual fuels and enhance the overall ignition performance [16]. MSW contains higher volatile content as compared with coal which will release at lower temperature, helps to decrease the reaction time needed during the combustion process [20].

Some literature suggested that volatile matter in MSW helped in the early ignition of the blended fuel. Most of the previous experiments were performed by considering the fundamental analysis without focusing on practical applications due to the non-homogeneity and high moisture content in MSW [21].

The aim of this study is to study thermal decomposition behaviour of lignite, MSW and their blends under combustion conditions to make it suitable to decrease coal imports to meet energy needs and disposal of solid waste in a sustainable manner. The objective of this study is to use the low-grade coal like lignite for the energy generation, with the combination of available MSW in the different form. Many researchers work on the lignite and MSW separately, but not consider them as a blend to form a new fuel. The effect of different weight percentages of MSW in the blends in the combustion process were also studied. The results from this study will help to understand the combustion characteristics of low-quality coal with MSW and will provide guidance in designing and operation of the boiler furnaces. The blends consider as a fuel is the innovation for the industry with low emissions. The combustion study of given blends was found to classify the best blend arrangement for achieving the desire goal. Various methodologies like direct method and Horowitz and Metzger method with different value of n, were used to analyse the data to discover the kinetic findings.

2 Materials and Methods

2.1 Materials and Sampling

The primary purpose of this investigation was to examine the general reaction kinetics using a TG analyzer. A TGA investigation of several samples was carried out in an oxy-fuel atmosphere at a heating rate of 10 °C·min^{-1}. For all samples, the sample size for the blended components is around 10 mg. TGA data were used to analyze the kinetic parameters of activation energy, and reaction order.

MSW used in current study was sorted and collected from Mehmood Boti, one of the main landfill sites in Lahore, Punjab in Pakistan. Combustible components were separated and selected as samples for experiments which included food and fruit peels, paper, wood and branches, plastic and waste fabric while non-combustible components such as glass, metal and sand were discarded. The components of MSW collected as received basis are listed in Table 1. Traditional test systems, particularly proximal and ultimate analyses, have remained effective in assisting in the classification of the thermal performance of lignite and MSW resources. To achieve homogeneity, all samples are prepared using a grinding mill and sieve machine [22]. The samples are milled first, then sieved to obtain a 0.3mm powder sample from a 38 mm pellet.

Table 1: Composition of raw MSW

Components	Combustible						Non combustible		
	Fruit waste	Food waste	Wood branches	Paper	Plastic	Textile	Sand	Glass	Metal
Wt. / %	38.27	13.45	15.03	9.86	16.40	6.09	0.9	0	0

The raw sample of municipal solid waste was washed with distilled water to make sure that there was no dust, sand or any other type of particle stick to the MSW. MSW was dried in drying oven for 24 h at 105 °C and after that samples were prepared by crushing, grinding and sieved to the required particle size of less than 4mm. Figure 2 showed MSW sample after treatment. All the components of treated MSW were mixed together according to weight percentage of MSW.

Lignite sample was collected from Tharparkar, Sindh province in Pakistan as major coal reserves found in this area. MSW was then mixed thoroughly with lignite with different weight ratios such as 10%, 20%, 30% and 50% respectively.

Samples for the TG analysis was separated, and for ultimate and proximate analysis, stored in rap and send to the laboratory. The mixture was pounded to homogenize, and the grain size was reduced to around 4 mm. A sample size of 10 mg of each configuration was obtained for the detail analysis.

Figure 2: MSW sample after treatment

2.2 Experimental Setup and Method

Heating values of samples were measured using LECO AC-500 bomb calorimeter having ≤0.05% precision under ASTM standards D-5865. Ultimate analysis of the samples was performed in CHN-S 628 analyzer having ≤0.06% precision by LECO Corporation under ASTM D-5373 to determine carbon, hydrogen and nitrogen in the samples. ASTM D-5016 was used to find total sulphur content present in the samples having ≤0.1% precision. Experiments were performed for proximate analysis in laboratory using muffle furnace to get the basic characteristics of combustible fuel by using ASTM standards D 3172-3175 having ≤0.01% precision under controlled temperatures.

Thermal properties of lignite, MSW and their blends were studied by using a TGA SDT Q600 analyser. TG and DTG profiles were analysed for obtaining weight loss curves. The tests were performed from ambient temperature to 980 °C under the heating rate of 10 °C/min. The tests were carried out by loading about 10 mg dried sample into the crucible at a constant flow rate of 20 ml/min under O_2 conditions. Every experiment were performed three time and use the best sample results in the manuscript.

2.3 Kinetic Analysis

The kinetic parameters of all categories of fuels have been estimated utilising thermogravimetric analysis (TGA) profiles applying a linear variant. At n = (0.3, 0.5, 0.67), and n=1, the reaction kinetics were modelled, and the values of Ea increased by a factor of two. For one order of reaction, the best line of fit has been provided for the apparent energy of activation values, In order to determine the kinetic parameters of the samples, Horowitz and Metzger method [23] was used to calculate activation energy using the Equation (1).

$$lnln \frac{Wi}{Wt} = \frac{Ea\theta}{RTs^2} \tag{1}$$

Where Wi is the initial weight, Wt is the weight at temperature t, θ is the difference between peak temperature and at particular weight loss, Ts is the peak temperature, R is the universal gas constant and Ea is the activation energy. By plotting lnln (Wi/Wt) vs θ, the activation energy can be calculated from the slope. The schematic diagram is shown in Figure 3.

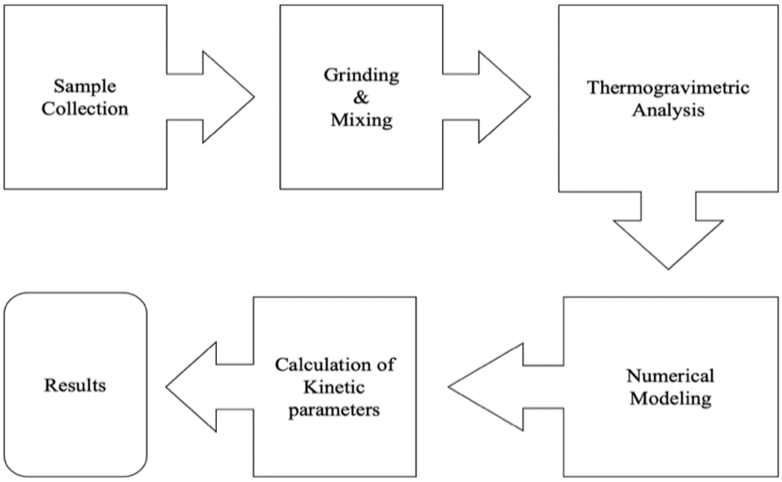

Figure 3: Schematic diagram of the whole study for making the blends

3 Results and Discussion

3.1 Proximate Analysis and HHV

The results from proximate analysis and calorific values of samples are listed in Table 2.

Table 2: Proximate analysis of MSW and Lignite and their Blends

Description	Moisture[a] %	VM[a*] %	FC[a**] %	Ash[a] %	HHV[a***] MJ/kg
Lignite	17.65	39.96	25.89	16.50	24.34
MSW	8.26	72.81	15.81	3.12	20.01
Blend 10/90% MSW/Lignite	16.41	46.31	22.35	14.93	23.74
Blend 20/80% MSW/Lignite	14.97	51.79	21.1	12.14	23.29
Blend 30/70% MSW/Lignite	12.06	57.97	20.66	9.31	22.81
Blend 50/50% MSW/Lignite	11.23	62.55	20.11	6.11	22.14

[a] *on dry basis*
**Volatile Matters*
***Fixed Carbon*
****High Heating/Calorific Value*

The materials used in this study as a fuel have different properties. Calorific value and fixed carbon content of coal is much higher than MSW. The amount of ash produced of MSW after the combustion of is less than lignite. MSW has higher volatile content which greatly helps in the early ignition of fuel at low temperatures make combustion process better. Lignite contains high moisture content than MSW due to water aquifers in the area [23]. The high volatile matter and low ash in blend 50/50 than other samples; might be due to the presence of high content of plastics than other ingredients. Blend 50/50 demonstrated the second lowest amount of moisture and suggested that there was no or small quantity of water-absorbing component (e.g., cloth) in its composition. Since the sample contains a high concentration of volatile matter and small moisture content, that results in low ignition temperature, and combustion can be initiated at a relatively lower temperature than the other samples. The samples differ in numerous behaviours but have a valuable quantity of fixed carbon, oxygen contents, moderate heating value, and significant volatile matters. These parameters determine the virtual part of the energy adaptation process for a specific goal. MSW materials contain more volatiles, carbon, hydrogen, and oxygen, the analysis results show that these materials have a reasonable heating value. The results obtained from proximate analysis agree with other results analysed by experiments for energy potential of Thar coalfields [24] and hydrothermally treated (HT) MSW [25].

3.2 Ultimate Analysis

The quality of the combustible fuel is generally described by the ultimate analysis. The results from the analysis are used to determine elemental composition of the fuel. The results of ultimate analysis of coal, MSW and their blends are shown in Table 3.

Table 3: Ultimate Analysis of MSW and Lignite and their Blends

Description	Carbon[a*] %	Hydrogen[a] %	Nitrogen[a] %	Sulfur[a] %	Oxygen[b] %
Lignite	64.68	6.04	2.65	1.18	8.95
MSW	56.91	8.74	0.89	0.19	30.15
Blend 10/90% MSW/Lignite	62.19	6.49	2.30	1.15	12.94
Blend 20/80% MSW/Lignite	61.59	6.91	2.11	1.04	16.21
Blend 30/70% MSW/Lignite	59.11	7.44	1.78	0.98	21.38
Blend 50/50% MSW/Lignite	57.97	8.01	1.02	0.79	26.10

[a] *on dry basis*
[b] *by difference*

Coal contains high sulphur content as compared to MSW while with the addition of MSW in different proportions helped to reduce the sulphur content in blends. The amount of oxygen is high in MSW than coal which helped in improving combustion process to achieve its ignition temperature early. Due to the strong interaction between carbon-carbon atoms, lignite breakdown was considerably slower. MSW have more oxygen, hydrogen, and less carbon contents than lignite, lowering the heating value because the breakdown of lignite atoms stimulated the high temperatures because of its small volatile matter and strong bonding of carbon-carbon atoms. Hydrogen produces water during combustion that needs to be removed from the furnace or evaporate due to heat. Nitrogen oxide is a major cause of smog, acid rain and the formation of delicate particulate matter in the atmosphere. Therefore, its concentration in samples should be as low as possible for a healthfriendly environment. The results obtained from ultimate analysis agree with other results analysed by experiments for energy potential of Thar coalfields [26] and HT treated MSW [27].

3.3 Ash Analysis

Ash is the unburnt residual matter left after the combustion process. Components present in ash and amount of ash describes the quality of the combustible fuel. The residual ash depends upon the individual fuel and the proportion of individual components in the blends. Proximate analyses of the samples in this study suggested that coal has 16.50% ash content more than in MSW found to be 3.12% and ash content decreased linearly with respect to the increasing proportion of MSW in the blends with coal. The proportion depends on the ingredients present in the blends during combustion. Samples contain organic matter integral to hydrogen and carbons. The wt.% ratio of Carbon/Hydrogen describes the number of hydrocarbons. The C/H ratio has slight fluctuations for raw material and leached samples. However, it must be perceived as a vital reduction in the C/H ratio of blended samples inspecting the high deduction of organic content according to the formation of blend.

3.4 Combustion Characteristics of Lignite and MSW

TG and DTG curves were investigated to study the combustion properties from these experiments. Initial weight loss was observed in lignite coal between 0-110 °C as it was used on received basis in this study which contains 48.89 % moisture content [24] much higher than MSW. The chemically bounded water in coal was also evaporated during this stage. After that with the release of volatile matter weight loss of the coal and MSW started which includes decomposition of hemicellulose and cellulose content. TGA curves of coal and MSW are shown in Figure 4.

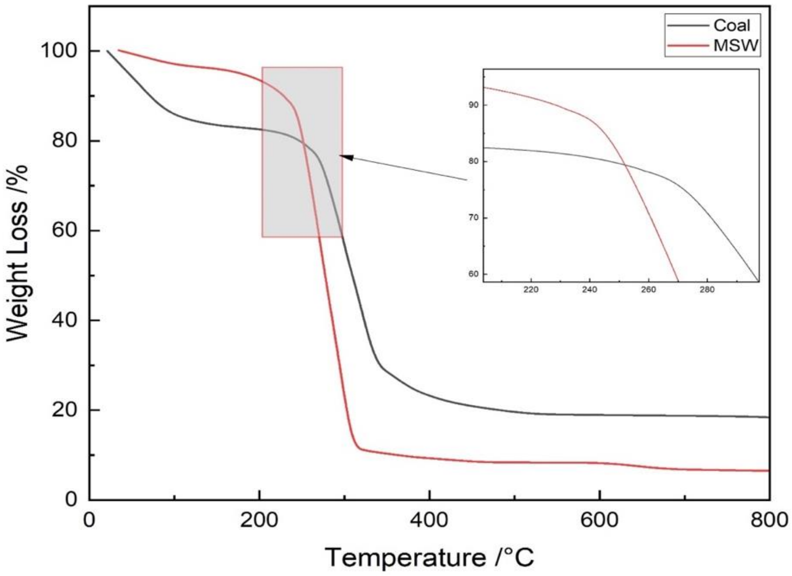

Figure 4: TG curves of Parent fuels (Lignite and MSW)

The ignition temperature was recorded at the point where curves of weight loss started to decrease [28] and burnout temperature was calculated as described by other authors for coal [14,19]. As it can be seen from the figure, the steep in weight loss of MSW curve was due to the combustion of higher volatile content which is the key component in initiating ignition process and lower amount of fixed carbon than lignite coal.

The percentages of ash remained of MSW and coal after combustion were 3.12 and 16.50 respectively. The ignition temperatures of coal and MSW were 312 °C and 258 °C respectively. The burnout temperature of coal was 64 °C was higher than MSW recorded as 517 °C. Due to high relativity of hemicellulose and cellulose materials, smaller span of temperature was required for completely burnout while lignin was low reactivity material and need larger span of temperature for burnout [29,30]. Combustion of volatile matter in coal occurred from 227 °C to 312 °C while combustion of fixed carbon and other residual matter occurred from 312 °C to 517 °C. In case of MSW, the reaction temperature for the combustion of volatile matter was from 194 °C to 258 °C and combustion of fixed carbon and other compounds with high boiling point was from 258 °C to 453 °C. Volatile matter in MSW was released at lower temperature than coal which will help to improve the devolatization process in coal. DTGA curves shown in Figure 5 explained the different stages during the combustion of MSW and coal. As the temperature increased, two weight loss peaks occurred in both samples during the combustion involving combustion of volatile matter in first stage and fixed carbon and other combustible matters like char etc. in second stage.

The weight loss of first peak in coal occurred at 60 °C with the peak value of 2.75 %/min due to high moisture content in lignite coal. Weight loss of second peak occurred with maximum peak value of 8.59 %·min^{-1} at 379 °C. While weight loss of first peak in MSW occurred at 78 °C with the peak value of 0.47 %·min^{-1}. weight loss of second peak occurred at 319 °C with maximum peak value of 9.36 %·min^{-1}. The second weight loss peak of MSW occurred at lower temperature than coal due to higher volatile matter in MSW. The combustion of volatile matter at lower temperature helps to improve overall ignition performance. The combustion behaviour of lignite coal from Thar coalfields, Pakistan and MSW agree with the results from other authors obtained from analyses on Indian coal and HT treated MSW.

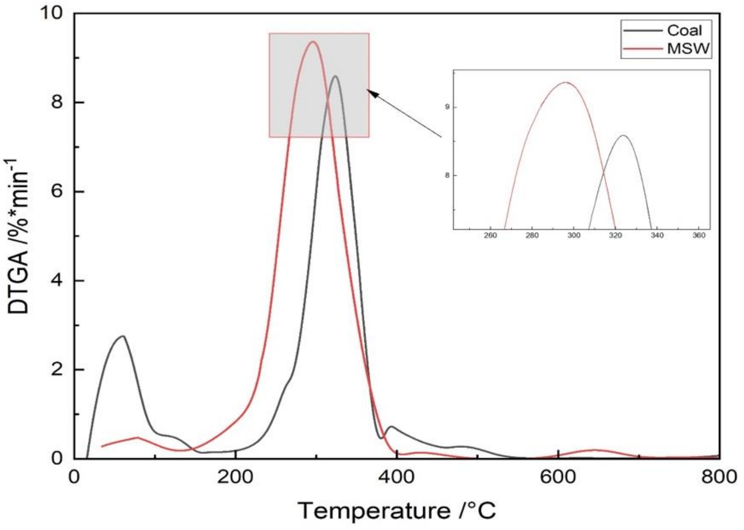

Figure 5: DTG curves of Parent fuels (Lignite and MSW)

3.5 Co-combustion Characteristics of Blends

TG curves of coal, MSW and their blends are shown in Figure 6. There was much difference in initial weight loss of coal and MSW due to high moisture content in lignite coal, however the weight loss curves of the blends occurred between individual fuel curves. As the proportion of MSW increased in the blends with coal, TGA curves were shifted to higher temperatures. Similar behaviour of combustion profiles was observed in combustion of anthracite coal with tobacco residue [31]. Due to higher volatile matter of MSW as compared with lignite coal fuel gets ignited early at low temperature in co-combustion techniques.

High volatile content in MSW helped the ignition of coal at lower temperatures than the required ignition temperature which can cause a fire hazard but also affected the devolatization of coal as the release of volatile matter found to be proportional to blending ratio with MSW. Volatile matter is the main reason for combustion in MSW and amount of fixed carbon in coal which needs higher energy to start combustion process. By combining these two fuels helped in improving overall ignition performance. Energy released from the burning of VM in MSW was sufficient to reduce the ignition temperature of coal.

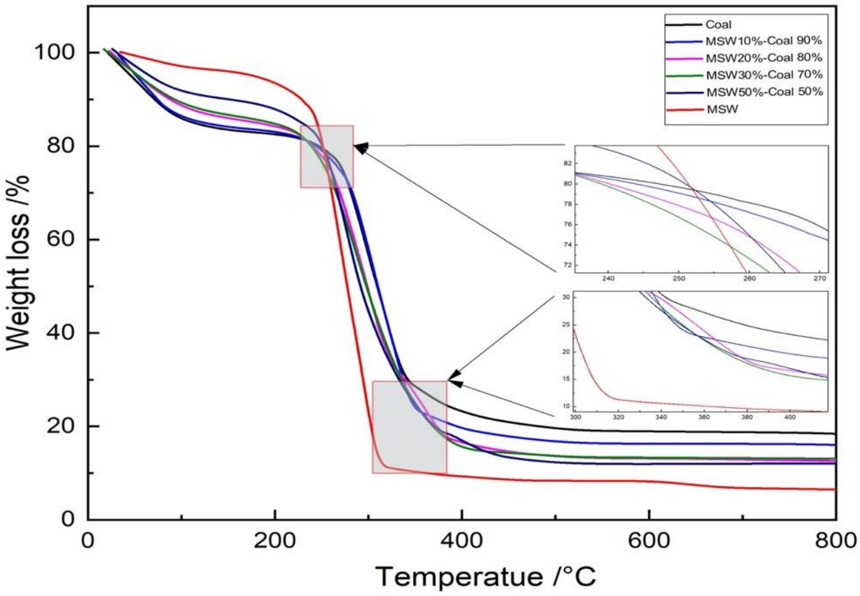

Figure 6: TG curves coal, MSW and their blends

Steep in weight loss profiles due to higher volatile matter in TGA curves was reduced as the MSW proportion in coal increased which differentiates the combustion behaviour of MSW with lignite coal. The combustion of blended samples occurred at higher temperatures making the combustion process efficient. Combustion of coal with 10% blend with MSW showed similar behaviour compared to coal with more weight loss. The combustion behaviour with 10% blend and individual coal sample agreed with other results from coal and paper mill sludge [9].

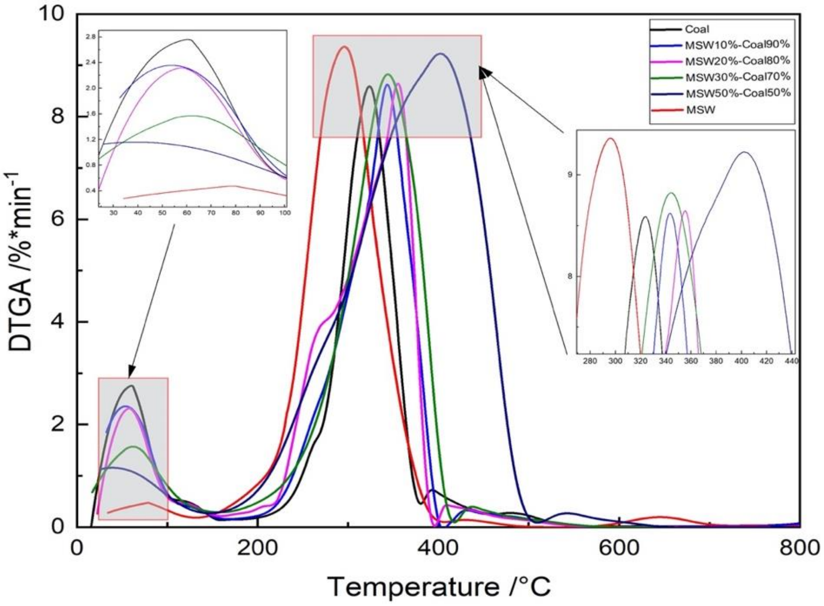

Figure 7: DTG curves of coal, MSW and their blends

DTG curves of coal, MSW and their blends are shown in Figure 7. There were two weight loss peaks in the DTG curves but three weight loss peaks were occurred in 20% and 50% blends of MSW with coal. As the proportion of MSW increased in blends with coal, the maximum mass loss occurred at higher temperatures than MSW and coal. The second peak shows the thermal degradation of the carbon matters. The shifting of the peaks as compared to their parent fuels, show the thermal stability and bonding of the blends. 50/50% blend have maximum thermal stability.

The thermal parameters of combustion profile are given in Table 4. Table shows a decrease in ignition temperature with the increasing portion of MSW in blends containing higher amount of volatile matter in MSW which has moved the combustion process to a higher temperature. Therefore, care must be taken with the utilization of MSW with lignite coal due to different types of ignition parameters.

Table 4: Combustion parameters of coal, MSW and their blends

Sample	T_v [a] °C	T_i [b] °C	T_m [c] °C	T_b [d] °C	DTG [e] %/min	DTG [e] %/min
Lignite	227	298	337	517	2.75	8.59
MSW	194	232	297	453	0.47	9.36
Blend 10/90% MSW/Lignite	224	296	342	513	2.35	8.62
Blend 20/80 % MSW/Lignite	212	273	354	483	2.31	8.64
Blend 30/70 % MSW/Lignite	208	261	345	477	1.56	8.82
Blend 50/50% MSW/Lignite	199	249	400	481	1.15	9.22

a Temperature at which volatile matter released
b Ignition temperature
c Temperature at which maximum weight loss of the sample occurred
d Burnout temperature
e Weight loss with respect to the peaks

Combustion of MSW and different proportions with coal showed more mass loss as compared to the combustion of coal. As the ratio of MSW was increased in coal for combustion, weight loss of samples decreased quickly. Mass stabilization in all curves of the blended samples were occurred in between of the individual fuels. The combustion parameters showed that blending of MSW with coal is an efficient way to improve combustion process. However, blending proportion of fuels should be properly determined for efficient ignition temperature and combustion stability.

3.6 Activation Energy

The kinetic parameters of lignite, MSW and their blends are listed in Table 5. The activation energy values depend on the various factors, such as, the interval of temperature, the procedure of mathematical analysis, ignition performances, and numerous others. Thus, the literature proposes an extensive diversity of activation energy results. Activation energy of MSW was much less than lignite in this study. The results show the weight decay and ignition of the blends might be complete in two sections, firstly MSW burn and help to start the ignition of the coal particles. The MSEs can drop the rate of E through the early phase of ignition, while it can recover the value of E over the crucial(lignite) ignition phase. These results reinforced improved ignition structures and the overdue ignition procedure [32] as shown in Table 5. After that activation energy decreased due to the fact that weak bonds in MSW are less resistant to heat than strong bonds in coal. The energy was maximum in 10% blended sample as compared to other samples which showed the increase in ignition temperature. Greater activation energy show that the withstand capacity of the sample. Normally, on the commercial point of view, it is necessary to have the withstand the fuel capacity then ignite.

Table 5: Activation energy parameters

Sample	Lignite	MSW	MSW/Lignite Blends			
			10/90%	20/80%	30/70%	50/50%
Activation Energy/ $kJmol^{-1}$	136.8	93.5	132.4	121.9	98.1	97.4

3.7 Heat Flow Diagram

Heat transfer analyses were used to determine if the reactions were endothermic or exothermic. According to DSC data, the thermograms changed from endothermic processes to mild exothermic reactions. Up to 180 °C, endothermic peaks were seen; afterwards, up to 1000 °C, modest exothermic peaks were observed. The degradation of lignocellulosic components is responsible for the peaks over 250 °C. The fuels have then deteriorated in the endothermic area. All blend fuels declined in the endothermic zone without self-heating influence, as per these thermograms as shown in Figure 8. From 180 °C to 600 °C, exothermic peaks were found for all types of blends; the peak can be attributed to light volatile combustion, while the other peak can be related to fixed carbon combustion.

The mass conversion profiles considered these strong exothermic peaks, which were confirmed by the study. Because of the oxidant environment, exothermic peaks were seen. The blend fuels then degraded again in the endothermic region. High activation energies were found in 10/90% samples, while lower activation energies were found in comparably harder samples. The fluctuation caused by the DTG performance curve of the material, influenced the inclination of the mass loss rate, and consequently affected the temperature interval used in calculations [33].

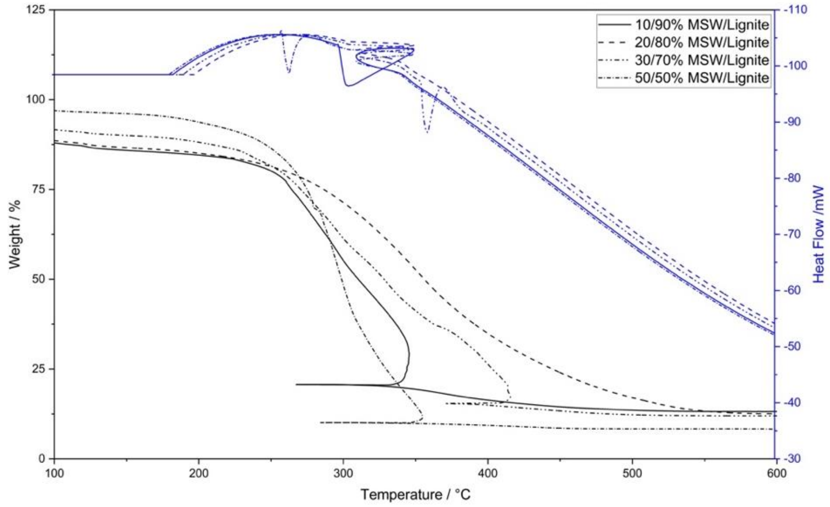

Figure 8: DSC curves of lignite and MSW blends

4 Conclusion

Co-combustion technique of lignite and MSW can be a viable way for not only waste management in a sustainable way for clean energy recovery but also for cost-effective and environmental benefits. Co-firing of lignite and MSW might deliver an attractive choice for the disposal under the waste-to-energy technique. Implementing co-gasification for thermochemical energy retrieval procedures at low temperatures can minimise material cost construction and reduce pollutant emissions. This process shows the reliability of co-combustion for blends. Also, the thermal stability of the lignite decreased with the increase of MSW. So, the minimum amount causes more stability in the blend and is more feasible. Thermal characteristics of Thar lignite, MSW and their blends were investigated by TGA analysis in oxyfuel circumstances. Mixing of MSW with lignite in different proportions increases the combustion stability and affects the ignition temperature of coal. Steep weight loss curves were reduced due to the addition of MSW with lignite increasing the overall ignition performance. With low proportion of MSW in blends as 10% did not significantly affect the combustion behaviour of lignite. With an increase in blending proportion of MSW, weight loss rate decreases but remains in between the individual fuels. Activation energy decreased up to 12% with increasing proportion of MSW in blends due to less resistivity of weak bonds in MSW to heat. Blending of 30% MSW with lignite showed better combustion stability profile as thermal degradation occurred at higher temperature as compared to the curves of other samples.

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Declaration of interest

The authors declare no there is no conflict of interest with CERAD or any other authority.

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