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Conference Paper · November 2013

DOI: 10.1115/IMECE2013-64415

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Proceedings of the ASME 2013 International Mechanical Engineering Congress & Exposition
IMECE2013
November 15-21, 2013, San Diego, California, USA

IMECE2013- 64415

THERMOGRAVIMETRIC ANALYSIS AND CHARACTERISATION OF YARD WASTE AS A FEEDSTOCK TO GASIFICATION PROCESS

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ABSTRACT

Gasification has great potential to make use of the biomass and wastes as a source for energy among various thermochemical conversion processes. The aim of this work is to study the suitability of yard waste for energy conversion using gasification process by Thermo gravimetric analysis. Yard waste (consisting of leaves, twigs and grass clippings) is collected from the National Institute of Technology Warangal. It is then dried and ground to a particle size of less than 250µm for thermo gravimetric study. Before going to thermo gravimetric analysis; the sample is analyzed to measure the main properties that affect thermal conversion. Moisture content present in the sample is determined by the oven drying method. Proximate is done according to standard ASTM test methods and ultimate analysis is conducted using elemental analyzer. Finally thermo gravimetric analyses is performed at various heating rates of 10, 30, and 50°Cmin^{-1} in nitrogen (inert) and air (oxidizing) atmospheres. The weight losses of yard waste in inert atmosphere occur in three stages and in air it occurs in four stages.

INTRODUCTION

The depletion of fossil fuels and environmental problems arising due to present technologies making the world turning towards the cleaner methods for power generation. Biomass gasification is one such, which can be used for production of electricity in environmental friendly manner. Various types of biomass include agriculture residues, municipal waste, forest residuals, aquatic plants, energy crops etc. Considering the municipal solid waste, the major fraction of this waste consists of domestic waste, paper waste, and yard wastes [1]. In earlier days yard waste is not separated from the municipal solid-waste. By practicing the collection of the yard waste separately, it can be used for energy recovery options.Thermogravimetric analysis (TGA) is one of the major thermal analysis techniques used to predict thermal behaviour of the material during thermochemical conversion under various atmospheres. During thermal decomposition of straw, Ghaly and Ergudenler observed that the biomass degradation rate is increased with increase in heating rate in both air and nitrogen atmospheres [2].The fourier transform infrared spectroscopy (FT-IR) analysis provides the information about the chemical structure and surface functional groups of a material [3], which helps to know the characteristic properties of the compound. Atoms in molecules are in continuous motion with respect to one another. They vibrate about the mean position. The infrared spectrum of a compound is the superposition of absorption bands of specific functional groups.

MATERIAL AND METHODS

Sample preparation:
Approximately 5-10 kg of Yard waste is collected from the dump sites of National Institute of Technology Warangal. From this around 2 kg of material is taken and ground thoroughly with the help of a small size grinding mill. Then sieve analysis is done using the sieves with mesh numbers 30 (600µm), 40 (425µm), 50 (300µm), 60 (250µm) and 70 (212µm) for

obtaining uniform particle size distribution and to narrow the range of particle size less than 250 µm. Finally the sample is stored in air tight plastic container for thermogravimetric analysis.

Proximate analysis and Ultimate analysis:

The elemental composition of the prepared sample is measured by using CHNS analyzer (Elementar Vario EL III, Elementar Analysensysteme GmbH, Germany).The proximate analysis is done according to the test methods given in the ASTM standards D 1102,E 871 and E872 and shown in the table.1.

Fourier Transform Infrared Spectroscopy:

The FT-IR analysis is done for the yard waste using Infrared Spectrometer (Thermo Nicolet, Avatar 370) in the spectral range of 4000-400cm^{-1} at 4cm^{-1} resolution.

Thermogravimetric analysis:

TGA analysis is conducted using Thermogravimetric analyzer (Perkin Elmer, Diamond TG/DTA) in the temperature range of 15 to 900^{o}C with the prepared samples. The experiments are performed at heating rates of 10, 30 and 50^{o}C/min in air (oxidizing) and nitrogen (inert) atmospheres.

RESULTS AND DISCUSSIONS:

FT-IR study:

The functional groups present in the sample are identified by the absorption bands listed in the table 2 and the spectra is shown in the figure1.The broad absorbance obtained between 3400-3200 cm$^{-1,}$ is attributed to O-H group stretching of polymeric materials, presented in cellulose, hemicelluloses and lignin. The bands 2921, 2852 cm^{-1} are corresponds to asymmetric and symmetric stretching of C-H bond respectively. These are saturated aliphatic group frequencies. The adjacent peaks observed at 1617, 1507, 1433, 1323, 1254 cm^{-1} are aromatic group vibrations with C=C-C, C=C, C-H, C-N and aryl-O bond stretches respectively. The high intensity band at 1035 corresponds to vibrations of C-N bond stretch, which is a characteristic of primary amines. The less intensity absorption bands at 876,774 cm-1 are due to the vibrations of aromatic C-H bond stretch with meta (1, 3) distribution. The absorption peak at 531cm-1 is the Stretching vibrations of C-I (Iodo compounds) bonds. The absorbance peak at 468 cm-1 explains the vibrations of Si-O bonds.

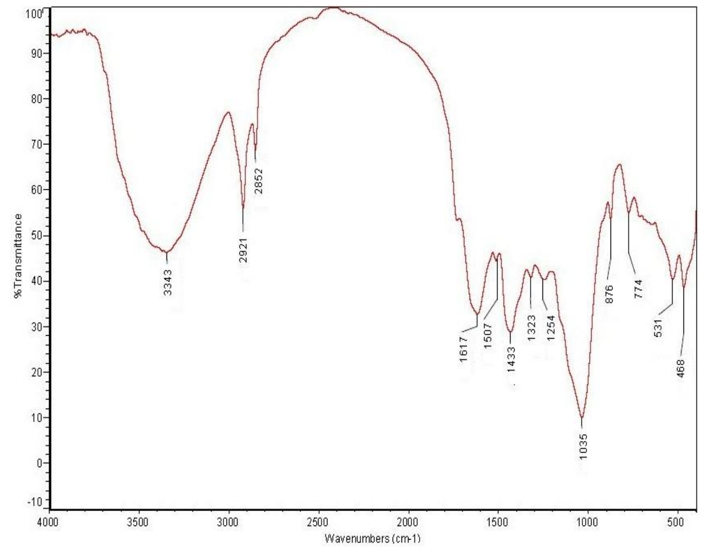

Fig. 1: Infrared Spectra of yard waste

Table 1. Ultimate and proximate analysis of yard waste

Proximate analysis (wt. %)	
Moisture content	5.4
Volatile matter	63.42
Fixed carbon	17.48
Ash	13.7
Ultimate analysis (wt. %)	
Carbon	34.25
Hydrogen	3.22
Nitrogen	1.10
Sulphur	0.42
Oxygen	47.31
[a]Higher heating value (MJ/kg)	15.96

a- calculated from proximate analysis [4].

Table.2. Interpretation of yard waste data collected from FT-IR technique [5].

Wavenumber, cm^{-1}	**Functional group**
3343	O-H, Normal polymeric stretch
2921	C-H, Methylene asymmetric stretch
2852	C-H, Methylene symmetric stretch
1617	C=C-C, Aromatic ring stretch
1507	C=C, Aromatic stretch with multiple bonds
1433	C-H, Methyl asymmetric stretch
1323	C-N, Aromatic tertiary amine stretch
1254	Aromatic ethers, aryl-O stretch
1035	C-N, Primary amines stretch
876	Aromatic C-H stretch , 1,3-Disubstitution
774	Aromatic C-H stretch , 1,3-Disubstitution
531	Aliphatic iodo compounds, C-I stretch
468	Si-O-Si bond stretch

Thermal degradation characteristics of yard waste:

The thermal behavior of yard waste is observed in oxidizing and inert atmospheres at heating rates of 10°C/min, 30°C/min and 50°C/min using thermogravimetry. This provides the thermal data, which helps during the gasification process. The weight loss is calculated from the Mass vs. Temperature data obtained from the TGA curves at different heating rates (10°C, 30°C, 50°C) in air and nitrogen atmospheres, which is given in the table.3 and 4.

Table.3.Weight (W) loss data obtained from TGA plots at different temperatures (T) in air atmosphere.

10°C/min		30°C/min		50°C/min	
T (°C)	W (mg)	T (°C)	W (mg)	T (°C)	W (mg)
38	6.40	38	4.10	38	3.23
120	6.00	125	3.87	130	3.04
180	5.88	210	3.76	200	2.96
400	3.32	410	2.20	405	1.75
530	2.44	540	1.52	540	1.10
600	2.34	610	1.45	630	1.00
720	1.94	760	1.13	730	0.79

Table.4.Weight loss data obtained from TGA plots at different temperatures in N_2 atmosphere.

10°C/min		30°C/min		50°C/min	
T (°C)	W (mg)	T (°C)	W (mg)	T (°C)	W (mg)
38	1.37	38	2.43	38	1.43
115	1.27	125	2.30	130	1.32
180	1.22	200	2.21	200	1.25
530	0.39	550	1.06	570	0.42
590	0.32	640	0.94	620	0.37
730	0.10	750	0.72	760	0.16

Oxidizing (air) atmosphere:

In this atmosphere, the thermal degradation occurs in four stages at all the heating rates (10°C/min, 30°C/min and 50°C/min) shown in figures 2-4. Out of which the first stage (38-120°C) may corresponds to loss of water [6].The weight loss in this stage are 6.14%, 5.65% and 5.73% for 10, 30 and 50°C/min respectively. The second stage for a scan rate of 10°C/min starts at around 180°C and ends at 400°C with a maximum weight loss of 40.1% throughout the process. Similarly for 30°C/min (210-410°C) and 50°C/min (200-405°C) the weight loss observed as 38 and 37.52 % correspondingly. The third stage for heating rates of 10, 30 and 50°C/min starts around 400°C and ends in the range of 500-540°C. The weight losses in this stage are 13.65 %, 16.02% and 20.20% respectively. This maximum weight loss in second and third stages is due to the exothermic reactions occurring during these stages. The fourth stage may corresponds to the decay of carbonates [7] with minimum weight loss of 6.31(10°C/min), 7.77 (30°C/min) and 8.33% (50°C/min).The percent degradation (Degr. %) of yard waste in each stage of the conversion process is given in the table 5.

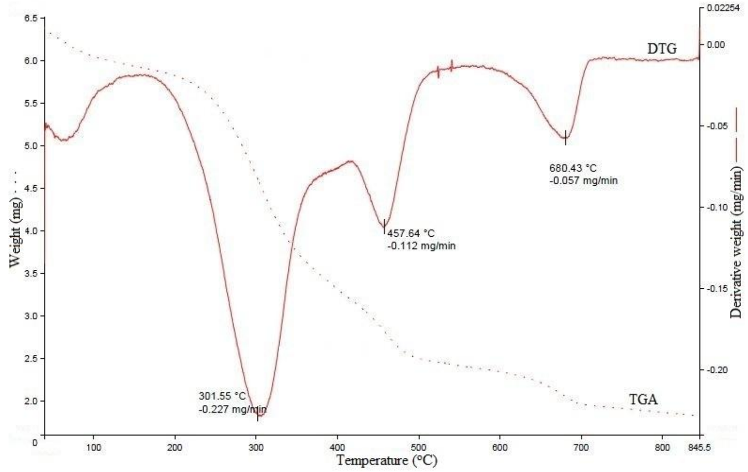

Figure 2.TG and DTG curves of yard waste sample at a heating rate of 10°C/min in air atmosphere.

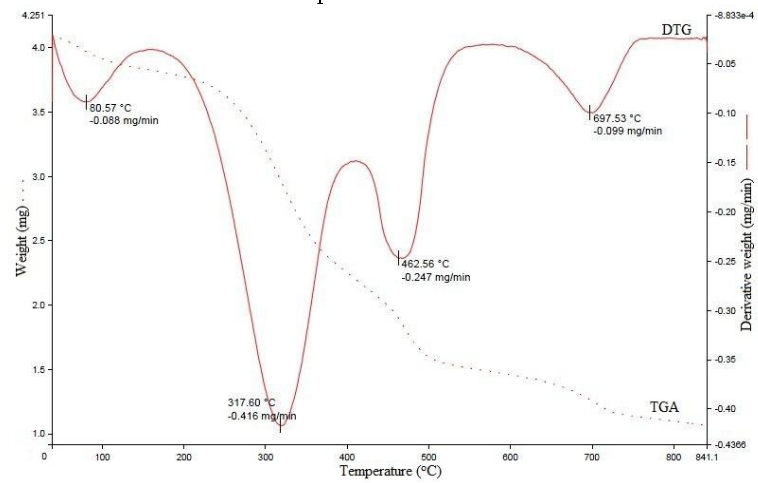

Figure 3.TG and DTG curves of yard waste sample at a heating rate of 30°C/min in air atmosphere.

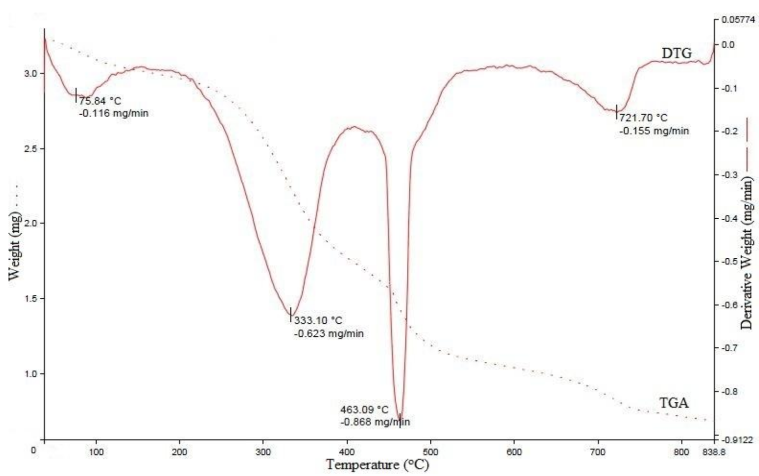

Figure 4.TG and DTG curves of yard waste sample at a heating rate of 50°C/min in air atmosphere.

Table.5. Degradation of yard waste in various zones at different heating rates in air atmosphere

	10°C/min		**30°C/min**		**50°C/min**	
	T (°C)	Degr. (%)	T (°C)	Degr. (%)	T (°C)	Degr. (%)
Stage 1	38-120	6.14	38-125	5.65	38-130	5.73
Stage 2	180-400	40.1	210-410	38	200-405	37.52
Stage 3	400-530	13.65	410-540	16.62	410-540	20.20
Stage 4	600-720	6.31	610-760	7.77	630-70	8.33

Inert (Nitrogen) atmosphere:

In this atmosphere, the degradation of the material occurs in three stages. Similar to the oxidizing atmosphere, the weight loss (6.78, 5.4 and 7.07% for 10, 30, 50°C/min respectively) in first stage is due to the removal of moisture content present in the material. For most of the biomasses the removal of moisture content or the drying process occurs around 125°C [8]. In the other two stages, the second stage corresponds to the maximum proportion of the weight loss compared to other stages. The temperature ranges of second and third stages are 180-530°C and 590-730°C for a heating rate of 10°C/min, 200-550°C and 640-750°C for a heating rate of 30°C/min, 200-570°C and 620-760°C for a heating rate of 50°C/min.The weight losses corresponding to these stages are 60.54% and15.67%, 47.48% and 9.08%, 57.97% and 14.70% respectively shown in table 6. Here the most of the weight loss is occurred in second stage, which corresponds to the devolatization reactions occurring during the pyrolysis process. The thermograms of these are shown in figures 5-7.

Table.6. Degradation of yard waste in various zones at different heating rates in nitrogen atmosphere

	10°C/min		**30°C/min**		**50°C/min**	
	T (°C)	Degr. (%)	T (°C)	Degr. (%)	T (°C)	Degr. (%)
Stage 1	38-115	6.78	38-125	5.4	38-130	7.07
Stage 2	180-530	60.54	200-550	47.48	200-570	57.97
Stage 3	590-730	15.67	640-750	9.08	620-760	14.70

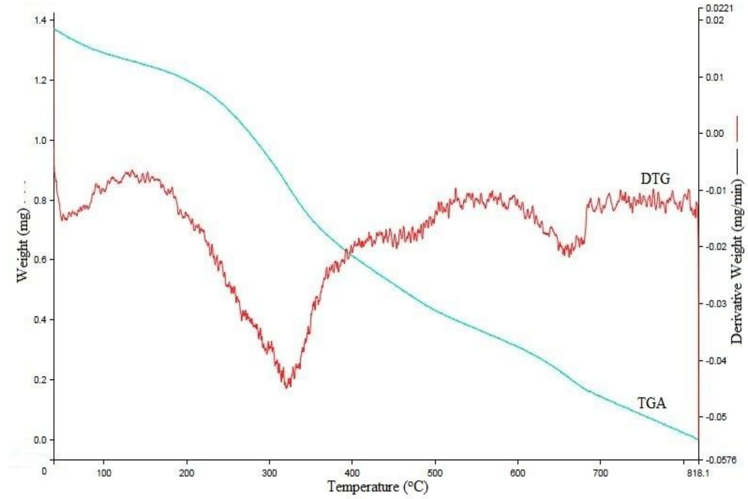

Figure 5.TG and DTG curves of yard waste sample at a heating rate of 10°C/min in nitrogen atmosphere.

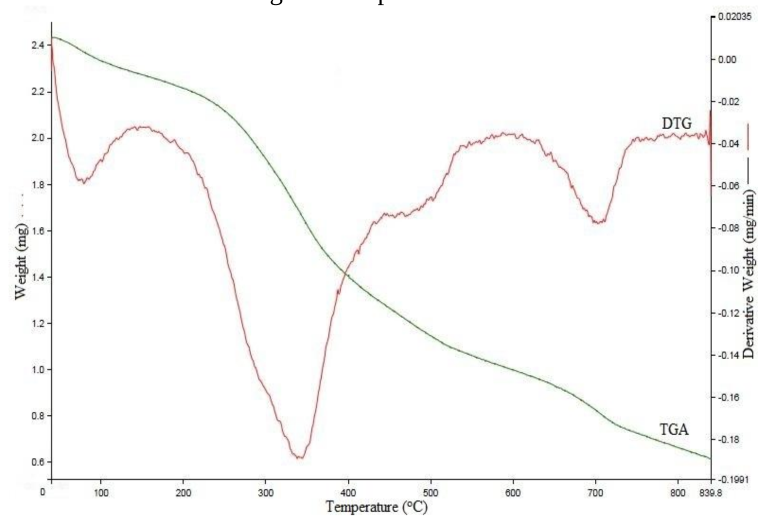

Figure 6.TG and DTG curves of yard waste sample at a heating rate of 30°C/min in nitrogen atmosphere.

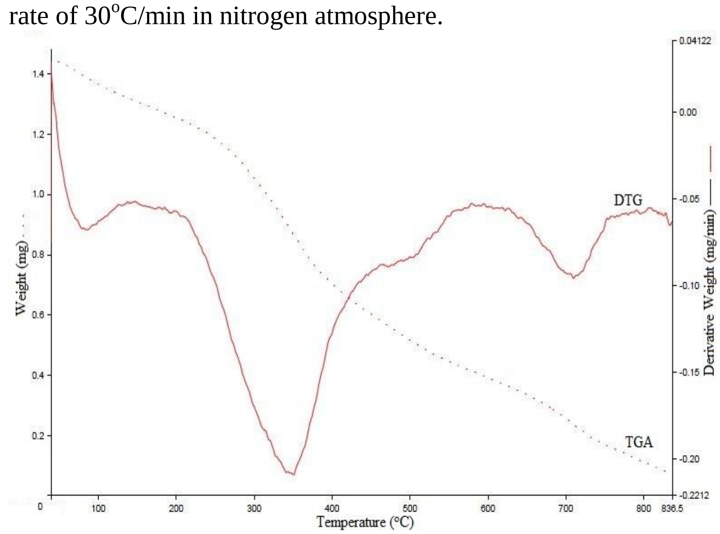

Figure 7.TG and DTG curves of yard waste sample at a heating rate of 50°C/min in nitrogen atmosphere.

Heating values:

The heating values obtained at various stages of degradation process in air atmosphere at different heating rates (10, 30, 50^{o}C/min) are given in the figures 8-10.From the degradation process and heat flow diagrams it is observed that, rigorous weight loss occurred in second and third stages of the process. From this, it is revealed that the majority of the heat flow in the process occurred in these two stages. The heating values in the second and third stages at a heating rates of 10^{o}C/min, 30^{o}C/min and 50^{o}C/min are -1726.8378 J/g -1223.8933 J/g , -5584.3034J/g -7386.2263J/g and -3745.2042 j/g -6818.1564 J/g respectively.

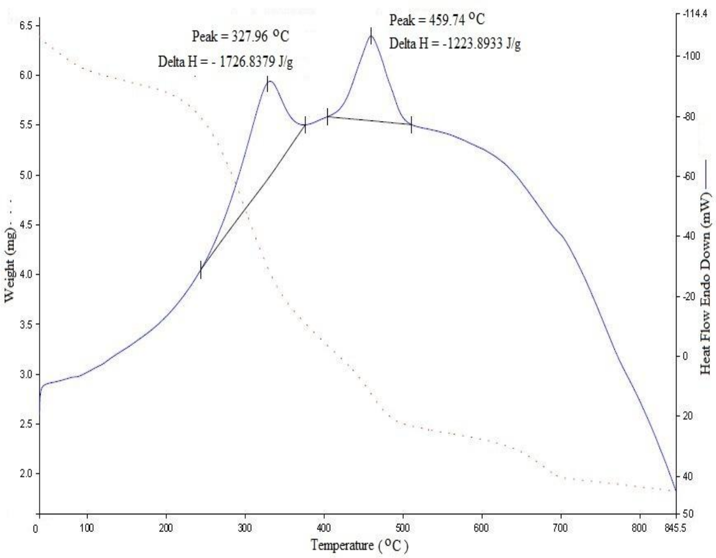

Figure.8. Heat flow diagram at heating rate of 10^{o}C/min.

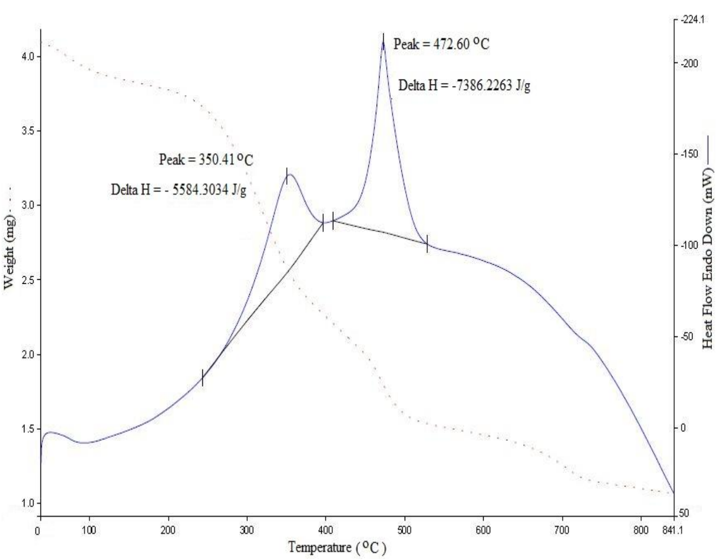

Figure.9. Heat flow diagram at heating rate of 30^{o}C/min.

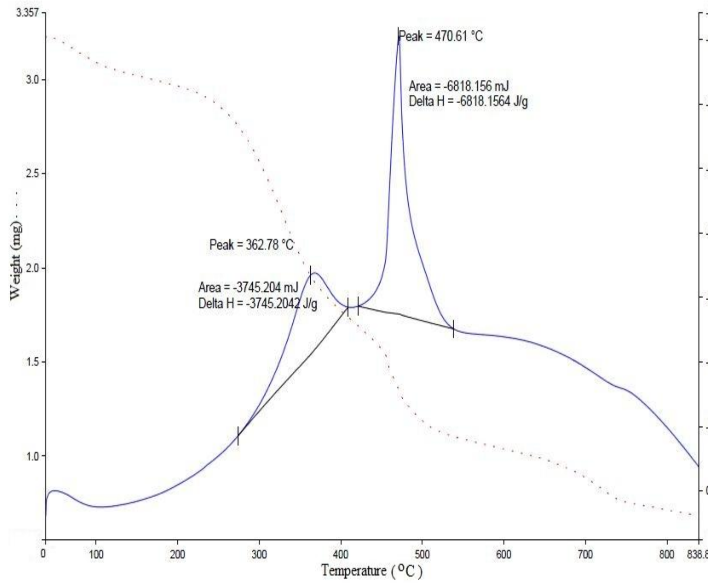

Figure.10. Heat flow diagram at heating rate of 50^{o}C/min.

CONCLUSION

During the thermal decomposition of yard waste, it is observed that, the total degradation of the sample increases with the increasing in the heating rates. The thermal degradation of yard waste in pyrolysis zone is high in nitrogen atmosphere compared to air. Due to the presence of oxygen, the length of pyrolysis zone in air is smaller compared to inert atmosphere, where there is no accessibility of oxygen throughout the process. This lowers the residence time of yard waste in pyrolysis zone in air. The weight loss in oxidizing atmosphere occurs in four stages, whereas in nitrogen it occurs in three stages. The first stage in both atmospheres is same (removal of moisture content) and occurs from ambient to a temperature of 120^{o}C.The rigorous weight loss in second and third stages in oxidizing atmosphere is due to the exothermic reactions (combustion). In case of nitrogen atmosphere (second stage), the weight loss occurs due to the active pyrolysis The heating values in various stages of degradation process increases with increase in heating rates.. Finally, the thermal stability of the yard waste up to 850^{o}C along with appreciable heating value makes the yard to use as feedstock to gasification process.

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