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A COMPARATIVE STUDY OF GASIFICATION OF FOOD WASTE (FW), POULTRY WASTE (PW), MUNICIPAL SOLID WASTE (MSW) AND USED TIRES (UT)

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The rate and volume of generation of waste material in the developing societies has increased significantly. Correspondingly the demand of energy has increased many folds. One of the options in this situation is to recover the energy value of the waste material for production of power and heat through gasification. Gasification of materials is a proven concept and its environmental benefits are known. The characteristic behavior and scope of gasification of four waste materials namely steam treated Food Waste (FW), Poultry Waste (PW), steam treated Municipal Solid Waste (MSW) and Used Tyres (UT) have been studied in a 10kg/hr hybrid gasification plant. This pilot plant consists of a fixed bed gasifier followed by a two in one cyclone scrubber for gas cleaning and a flare system. Various laboratory tests of these materials through proximate, ultimate analysis and stove test were conducted to establish their fuel characteristics. These materials were gasified to generate synthesis gas. It was observed that FW and UT offer sustainable potential for energy recovery. MSW on the other hand had considerable ash and had difficulties during gasification. PW could only be gasified when mixed with charcoal or high CV UT in order to balance against its high moisture. The gas analysis of the waste indicated significant quantities of hydrogen and carbon monoxide.

Keywords: Gasification, Hybrid gasifier, Food waste, Poultry waste,

1. Background

Gasification of biomass [1] is becoming popular for production of energy to meet the challenges of time. The rapid depletion of fossil fuel reserves, environmental regulatory constraints and availability of cost effective technologies capable of using low quality fuels for potential gains have led to the use of waste material as a green resource. Theoretically, almost all kinds of biomass with moisture content of 5-30% can be gasified [2] however most of the development work had focused on readily available fuels such as coal, charcoal and wood. The gasifier design and performance depends on fuel properties such as surface, size, shape, moisture content, volatile matter and carbon content [3]. The key advantages of gasification is its small footprint relative to typical incineration. It can be designed on a smaller scale and is cost effective thus support decentralized energy production and help to mitigate the NIMBY effect [4].

Gasification of waste materials is widely being favored because of many benefits i.e. recovery of energy, effective consumption of waste materials and earning carbon credits. Tremendous quantities of agricultural waste and waste generated due to industrialization and urbanization process are available which are currently creating great difficulties in handling and disposal [5].

The current study has been undertaken to characterize the gasification of steam treated Food Waste (FW), Poultry Waste (PW), steam treated Municipal Solid Waste (MSW) and Used Tyres (UT).

2. Pilot Plant Hybrid Gasifier

The typical design of downdraft gasifier has been improved through a number of innovations to allow uniform airflow through the fuel bed when fuel is allowed to flow under gravity without any restriction. The "Hybrid" gasifier allows better gasification of difficult residues without slagging or

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bridging. Some of the design details of the Hybrid gasifier are published elsewhere [6] while a patent is being filed for the same. A simplified diagram of the process and a picture plate is shown Fig. 1.

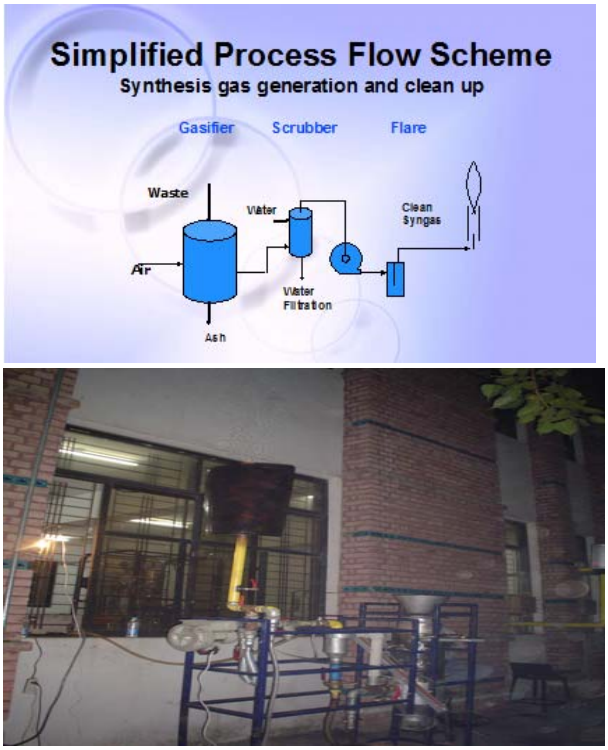

Figure 1. Process diagram and Picture Plate.

Briefly the pilot plant consists of a gasifier, a gas cleaning and tar removal system and a flare arrangement. The gasification process inside the gasifier can be divided into four distinct zones i.e. drying bunker, pyrolysis, oxidation and reduction zone. The details of the process are published elsewhere [7] and are available in various texts as well [8,9]. The primary air is introduced at the oxidation zone and the heat from this zone, typically operating at 1000-1200^{o}C is radiated to the fuel sitting above resulting it to pyrolyse. The synthesis gas is withdrawn at the bottom of the gasifier through a reduction zone using a spark free induced draft fan. The gas laden with dust, acidic and tarry products is sucked through the glowing bed of burning material and is reduced to form stable gas mixture comprising of hydrogen, carbon dioxide, carbon monoxide, methane, nitrogen and hydrocarbons. By controlling the air fuel ratio to the process a relatively complete breakdown of the tars is achieved.

The gasification system is kept under vacuum by an induced draft fan to enable the gases to pass through the scrubber where water is sprinkled counter currently. The gas gets cooled (~50^{o}C) and condensed. Any remaining tar that is carried with the gas is removed in a specially designed filter. The gas is ignited in the flare or diverted to an engine for generation of electricity. The gas generated is sampled from various stages of the process and temperature, pressure and flow rate are monitored.

3. Characteristics of Waste Materials

In order to establish the suitability for gasification, the characteristics of the waste materials listed in Table 1 were studied.

Table 1. Waste materials

Material	Abbreviation	Source	Preparation undertaken
Food Waste	FW	Super markets in UK	Drying to moisture < 15% & palletizing
Poultry Waste	PW	Local Chicken Shops	Mixing with charcoal
Municipal Solid Waste	MSW	Municipalities in UK	Drying to moisture < 15% & palletizing
Used Tires	UT	Local tires shops	Shredding & mixing

The pallets of FW and MSW are shown in Figures 2 &3 and the characterization of each material is given in Tables 2 to 5.

Figure 2. Pallets of FW

Figure 3. Pallets of MSW

4. Gasification Performance

The performance of each material was established through gasification test by operating under similar condition. Both FW and UT achieved self sustained gasification however in the case of MSW and Poultry Waste, having low CV, were mixed with waste cooking oil and Tyre crumbs respectively. The synthesis gas flare flames are shown picture plate below (see Figure 4). The synthesis gas analysis of each case is summarized in Table 6.

Figure 4. Picture Plate of Flare of Synthesis Gas

Table 2. Characterization of food waste

Feature	Method	Observation/Results
Appearance	Visual inspection	Dark smelly sticky material
Density (kg/m^3)	Bulk	535 as received
Composition(mass %)	Proximate Analysis (%)	29.3 Moist, 51.1 VM, 14.6 Fixed C, 4.9 Ash
	Ultimate Analysis (%)	56.65 C, 8.76 H, 23.54 O, 3.95 N, 0.19 S, 6.9 Ash
Level of Toxic trace matter (µg/g)	X-Ray Fluorescence Spectrometry (XRF)	Hg <2, Cd < 0.1, Ar < 1, Cr < 15, Ti < 344.1, Pb < 15.4
Heating value (MJ/kg)	Calorific Value	26.33
Slagging propensity	Stove Test	Satisfactory

Table 3. Characterization of poultry waste.

Feature	Method	Observation/Results
Appearance	Visual inspection	Chicken litters, blood, flesh, other wastes
Density (kg/m^3)	Bulk	335
Composition ([mass %)	Proximate Analysis (%)	7.5 Moist, 40.3 VM, 8.4 Fixed C, 43.9 Ash
	Ultimate Analysis (%)	22.4 C, 3.8 H, 27.1 O, 2.6 N, 0.7 S, 43.4 Ash
Level of Toxic trace matter (µg/g)	X-Ray Fluorescence Spectrometry (XRF)	Not Available
Heating value (MJ/kg)	Calorific Value	9.24
Slagging propensity	Stove Test	Not Satisfactory

Table 4. Characterization of municipal solid waste.

Feature	Method	Observation/Results
Appearance	Visual inspection	Dark smelly sticky material
Density (kg/m^3)	Bulk	452
Composition (mass %)	Proximate Analysis (%)	50.9 Moist,18.8 VM, 7.6 Fixed C, 22.7 Ash
	Ultimate Analysis (%)	36.35 C, 4.96 H, 10.13 O, 1.43 N, 0.83 S, 46.3 Ash
Level of Toxic trace matter (µg/g)	X-Ray Fluorescence Spectrometry (XRF)	Hg <2.3, Cd <1.2, Ar <1, Cr< 15, Ti< 2874, Pb< 755.7
Heating value (MJ/kg)	Calorific Value	9.35
Slagging propensity	Stove Test	Not Satisfactory

Table 5. Characterization of used tyres.

Feature	Method	Observation/Results
Appearance	Visual inspection	Dry shredded material with litters
Density (kg/m^3)	Bulk	657
Composition (mass %)	Proximate Analysis (%)	1.2 Moist, 52.6 VM , 36.2 Fixed C, 10 Ash
	Ultimate Analysis (%)	57 C, 8.5 H, 4.5O, 3.5 N, Cl 1.0, 9.5 Ash
Level of Toxic trace matter [µg/g]	X-Ray Fluorescence Spectrometry (XRF)	Hg <1.4, Cd <38.5, Cr< 19.5, Ti< 0.057%, Pb< 431.4
Heating value (MJ/kg)	Calorific Value	23.2
Slagging propensity	Stove Test	Satisfactory

Table 6. Gasification performance comparison.

Parameter	Food Waste (FW)	Poultry Waste (PW)	Municipa l Solid Waste (MSW)	Used Tires (UT)
Ar (%)	2.21	----------	2.07	-------
N_2 (%)	67.01	60.5	67.34	40.06
CH_4 (%)	2.56	0.9	1.54	2.8
CO (%)	11.29	28.1	14.89	25.13
CO_2 (%)	10.13	3.7	8.4	19.5
O_2 (%)	1.67	-----------	1.2	1.01
H_2 (%)	5.13	6.1	4.58	10.6
Other hydrocarbons	------	0.7	----------	1.67
CV MJ/m^3	7	4.9	3.1	6.76

5. Conclusions

The waste materials made available, except tyres, had significant quantity of moisture. Accordingly drying was undertaken to make it suitable for gasification. The calorific value of synthesis gas from FW was observed to be highest (7 MJ/Nm^3) while that of MSW it was observed to be only 3.1 MJ/Nm^3. The calorific value of UT and PW was observed to be in the range of 5-7 MJ/Nm^3. Both materials demonstrated good gasification prospects. FW had remarkable calorific value mainly because of the reason that the supermarket waste from UK had expired cheese and butter present in it. The burning rate was significantly rapid and the shape of flame was similar to wood. Since no pre-treatment was required for UT except cutting them into pieces it was observed to be most suitable for gasification.

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