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Energy Production from Gasification of Solid Waste in A Fixed Bed

A. S. Olufemi[1*], I. Tulagha-Ocholi[2], D.E. Makpah[3] and P. S. Akanji[4]
[1]Department of Chemical/Petroleum Engineering, Niger Delta University, Wilberforce Island, Nigeria.
[2,3]Department of Agricultural/Environmental Engineering, Niger Delta University, Wilberforce Island, Nigeria.
[4]Department of Chemistry, University of Johannesburg, Johannesburg, South Africa.
*Corresponding author: A.S. Olufemi, Tel.: +2348033311087, E-mail: adestanford.olufemi@gmail.com
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ABSTRACT

The municipal solid waste gasification technology has been investigated using a pilot scale fluidized bed gasifier for the recovery of energy. This work focuses on the production of synthesis gas from municipal solid waste (agriculture waste, orange fruit waste and egg cover), the production of energy from municipal solid waste by combustion in fluidized bed gasifier and air discharge are used for power generation. As feedstock preparation plays an important role to increase performance of gasification, steps of feedstock preparation (sorting, shredding and dying) are explained in detailed. Syngas production and clean-up and burning process is explained. The composition of syngas produced at different stages of the experiment is also presented. The purpose of this study was to estimate the potential of gasification process an alternative to the combustion of municipal solid waste. Fluidized bed gasifier uses a relatively small amount of oxygen or water vapor to regenerate the organic compound into a combustible gas. This study found that about 65 % of the original energy of solid waste is converted to syngas and 23 % is converted to char with remaining 12 % as residue loss. The primary energy conversion is done by burning syngas in a 0.5 MW gas engine through an otto cycle power generation. The ratio of steam to biomass effects the composition of product gas. Silica sand and municipal wastes are used as bed material in fluidized bed gasifies.

Keywords: *Fluidized Bed, Energy Production, Gasification, Solid Waste*

INTRODUCTION

As years go way, the demand of energy increases, and becomes clearer the need to search for new sources, renewable and non-polluting. That is the reason why in these last years the development and research on renewable sources of energy is coming more and more significant. Management and treatment of urban and industrial solid waste (garbage, recyclable materials, organic waste and hard waste) can mitigate adverse impacts on environment and human health, and also can support economic development and quality of life [1]. Municipal solid wastes (MSW), associated with nonindustrial human activity, are continually generated in large amounts around the world, creating problems with their disposal. Hence, enforces to think for sustainable waste disposal. A number of thermo-chemical waste treatment methods (i.e. waste-to-energy conversion pathways such as, Pyrolysis, Gasification and Incineration) can transfer solid waste into energy, while gasification technology provides an efficient and environmental friendly solution to produce energy in the form of syngas [2]. Also here, gasification is the technique, which provides better solution to a problem than incineration technology [3].

Today, the world requirement for renewable energy sources is the key factor in the consideration of the fluidized bed gasification system. Throughout gasification, the chemical energy inside municipal solid waste could be defensive through production of synthesis gas, and volume of solid waste can be quick decrease. Municipal waste was no more treated as the valueless garbage, the solid waste is rather perceived as resource in the present time. Associated waste management system attempt a pliability of waste analysis option base on different waste fraction like plastics, glass, organic waste. The gasification technology or approach could be analyzed by the environmental, social or environmental point of view.

Recently, a number of Alternative Waste Technologies (AWTs) have been developed for solid waste treatment. AWTs illustrate processes that generally, (a) redirect waste away from landfill, (b) pick up more resources from the waste stream and (c) reduces the impact on the environment [4]. Following a detailed investigation and using multi-criteria analysis (MCA), it has been established that Gasification is a suitable technology for Australia among a number of available AWTs (Anaerobic Digestion, Pyrolysis, Incineration and Gasification) [2].

Gasification is a process that converts biomass or solid waste by the addition of heat in an oxygen-starved environment. Recently, Kwon and Castaldi [5] investigated the enhanced gasification of municipal solid waste (MSW) using carbon dioxide (CO_2) as the gasification medium to achieve environmentally caring and energy efficient ways for the disposal of MSW. They found, there are two main steps of thermal decomposition of MSW: firstly thermal degradation step occurs at temperature between 280 ^{0}C and 350 ^{0}C and consists of the decomposition of the biomass component into light C_{1-3}-hydrocarbons. The second thermal degradation step occurs between 380 ^{0}C and 450 ^{0}C and is mainly attributed to polymer components, such as plastics and rubber, in MSW. Belgiorno *et al.* [6] investigated the state of gasification technology, energy recovery systems, pre-treatments and prospect of syngas use with particular attention to the different process cycles and environmental impacts of solid wastes gasification. They identified gasification process offers energy recovery and reduce the emission of potential pollutants. Gasification with pure oxygen results in a higher quality mixture of carbon monoxide and hydrogen and virtually no nitrogen. Gasification with steam is more commonly called 'reforming' and results in a hydrogen and carbon dioxide rich 'synthetic' gas (syn-gas). The gas has a calorific value of 4-10 MJ/Nm^3 and can be used to generate electricity [7]. Typically, the exothermic reaction between carbon and oxygen provides the heat energy required to drive the pyrolysis and char gasification reactions [8]. There are six basic reactions (1 - 6), that must be considered during the process. All of these reactions are reversible and their rates depend on the temperature, pressure and concentration of oxygen in the reactor [9]. A schematic diagram of the whole process is shown in Figures 1.

$$
\begin{array}{ll}
C + O_2 \rightarrow CO_2 & -393\ kj/mol\ (exothermic) \\
C + H_2O \rightarrow CO + H_2 & +131\ kj/mol\ (endothermic) \\
C + CO_2 \rightarrow 2CO & +172\ kj/mol\ (endothermic) \\
C + 2H_2 \rightarrow CH_4 & -74\ kj/mol\ (exothermic) \\
CO + H_2O \rightarrow CO_2 + H_2 & -41\ kj/mol\ (exothermic) \\
CO + 3H_2 \rightarrow CH_4 + H_2O & -205\ kj/mol\ (exothermic)
\end{array} \quad (1)
$$

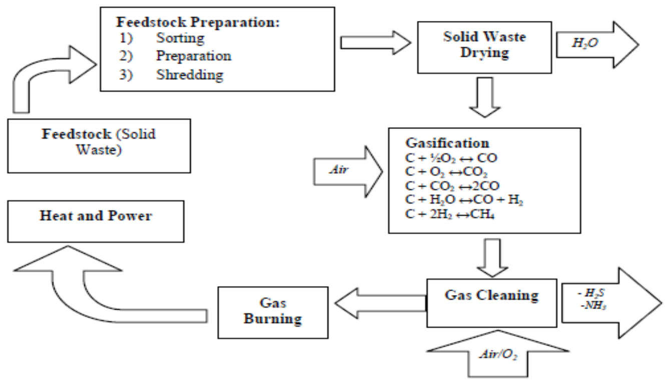

Figure 1. Schematic diagram of solid waste gasification process.

Many significant researches of waste gasification have been reported in the literature. Liu *et al.* [10] compared various technologies of MSW disposal and identified that thermal technologies have the most potential. Xiao *et al*. [11-13] studied the gasification characteristics of components in MSW and concluded that organic components could be gasified efficiently at 500 – 700 ^{0}C. The gasification characteristics of MSW were studied at 500 – 750 ^{0}C when equivalence ratio (ER) was 0.2 – 0.5 using a fluidized-bed gasifier by Xiao *et al.* [12]. They found that when temperature was 550 – 700 ^{0}C and ER was 0.2 – 0.4, low heat value of syn-gas reaches to 4000 – 12000 kJ/Nm^3. The purpose of this paper is to demonstrate a pilot scale gasification plant's experimental investigation of energy recovery from solid waste. Feedstock preparation, i.e. feedstock sorting, shredding and dying is explained in detailed. Partial fluidization was considered in this study in order to achieve faster dying and reaction rates. Composition of syngas at different stages of the experiment is presented. Syngas production and clean-up, emission control and mass and energy balance of the plant

MATERIALS AND METHOD

Description of Experimental Setup

In this study, a pilot-scale fluidized bed gasification process plant was used for energy recovery from municipal solid waste. Generally, gasification process includes two main tasks: preparation of feedstock materials and plant set-up. Feedstocks (Food waste, yard waste wood, textiles, paper, etc.) are collected from the City of Yenagoa, Bayelsa State. Collected wastes are prepared and sorted. To increase gasification performance, prepared feedstock was dried to reduce moisture.

In the gasifier, the solid waste is fed continuously at some high at a slow rate while steam and air is bed at the bottom. The solid waste undergoes devolatilization at the top of the gasifier. The char descends slowly through the reactor. For the reason that the char in the bed are moving gradually. Gasification process reaction takes place in the vessel in the presence of air producing raw syngas. Syngas cleaning is done to remove the pollution from produced raw syngas. The gasification vessel is a 12 in. diameter, and 8 fit. Long cylindrical stainless steel tube. The vessel could be operated at temperature as high 1200 ^{0}C. Figure 2 shows the experimental set-up of the gasification. And, this experiment was carried out by using silica sand as bed material.

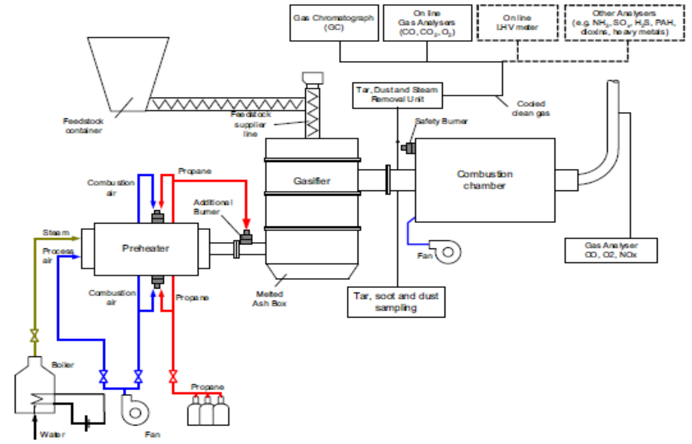

Figure 2. Schematic Diagram of the Experimental Setup of Solid Waste Gasification Process.

Experimental Procedure:

At the startup of each experiment, 2.5 kg of the bed material (silica sand) are fed to the fluidized bed reactor by the help of the screw feeder; the bed was fired using liquefied petroleum gas as a fuel at flow rate of 10 - 12 LPH. After the fluidized bed temperature increased a desired level, the flow of liquefied petroleum gas into the gasifier was stopped and the fruit waste, household was fed to the reactor by help of the attach feeder and the gasification start. Table 1 presents the operating parameters of the gasifier.

The filter was connected to outlet gas in which the solid particles are incarcerated by water and remaining particles captured by a filter of pore range0.01 - 0.04 micron. Earlier than going to an analyzer the moisture present in the gas were removed by passing it throughout silica gel transferable infrared coal gas analyzer was used to measure the concentration of hydrogen, carbon monoxide, methane and carbon dioxide in the outlet gas.

Table 1: Operating parameters studied and their range.

S/N	Operating Parameter	Range
1	Temperature	900 – 1100 ^{0}C
2	Bed material	3 - 4 kg
3	Feed rate	10 - 15 kg/hr
4	Equivalence ratio	0.20 – 0.50

RESULTS

A. Effect of varying temperature on product gas composition at biomass agriculture waste

Agriculture waste by product gas composition (vol. %) at different temperatures Effects of temperature on composition of syn-gas for agriculture waste are shown below.

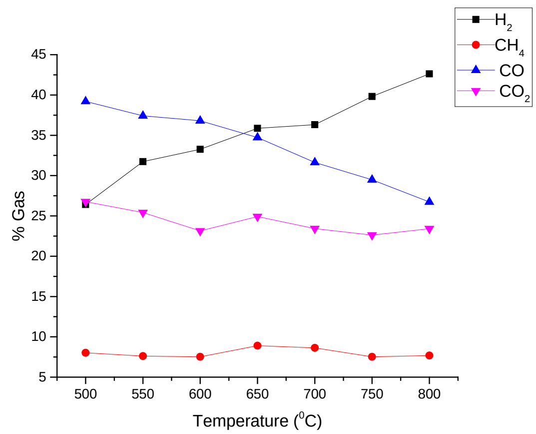

Figure 3. Temperature vs Product Gas Composition (vol. %)

B. Effect of varying temperature on product gas composition at household waste

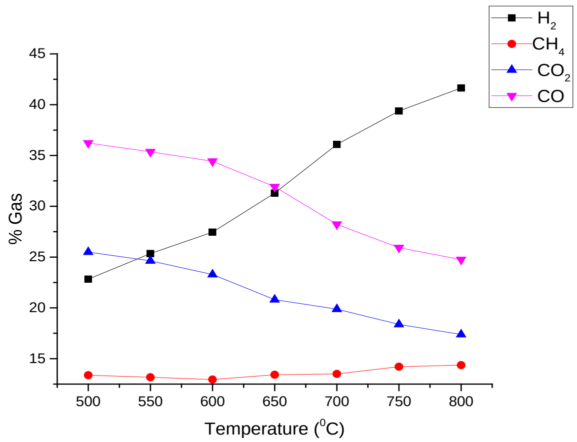

Figure 4. Temperature vs Product Gas Composition (vol. %)

C. Effect of varying temperature on product gas composition at fruit waste (orange)

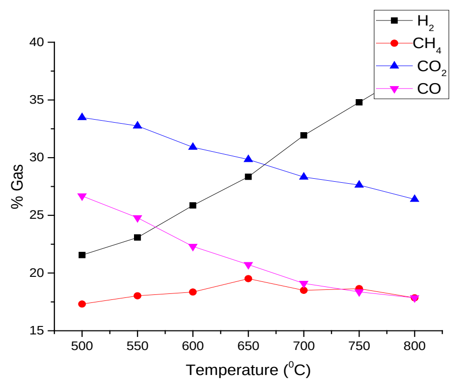

Figure 5. Temperature vs Product Gas Composition (vol. %)

D. Effect of varying temperature on product gas composition at egg cover waste

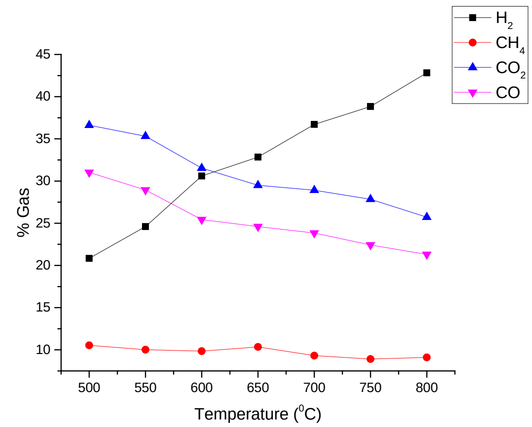

Figure 6. Temperature vs Product Gas Composition (vol. %)

DISCUSSION

All experiments have been carried out under equivalent condition concerning fuel load and fluidization settings. The temperatures in the gasification zone, which are characterize the operating point at was between 900 - 1100 ^{0}C in all experiments. The report is show that fluidization behaviors of rice husk, household waste, egg cover and fruit waste (orange) are summarized in four experimental data. The convenience of comparison, all the report value have been converted to SI unit and air flow rate has been converted to corresponding equivalence ratio, which is defined the ratio of actual to stoichiometric mass of air supply per kg of fuel. In the deficiency of stoichiometric air or elemental composition in the reports. Therefore, a value of 10 kg/hr of dry household waste, egg cover, rice husk and orange waste taken.

Since, the fluidized bed gasifier is an endothermic reaction; the product gas composition is responsive towards temperature change. It was observed that the concentration of hydrogen increased with increased temperature, and the concentration of carbon monoxide remain constant over the range of temperature. As a result with increase in temperature and concentration of methane decreases in the product gas and this is approach to increases concentration of hydrogen. The carbon dioxide is concentration decrease with increase in temperature since higher temperature favors endothermic formation of carbon monoxide and carbon dioxide vie boudoirs reaction.

The gasification uses a relatively small amount of oxygen or water vapor to convert to organic compounds into a combustible gas. The volume of process gas per unit that could be integrated with combined cycle turbine or reciprocating engine and therefore synthesis gas converted to electricity more efficiently than the steam boilers used in combustion of municipal solid waste. Disadvantages are need for complicated pre- processing of the municipal solid waste to refuse derived fuel and formation of the inorganic compounds and that must be removes from the product gas prior to using in a turbine.

CONCLUSION

The gasification process offers extensive energy recovery and reduces the emission of potential pollutants. It is considering an integrating and alternative to the conventional technology for the thermal treatment of solid waste. The principal difficulty of solid waste gasification, in particular for municipal solid waste, furthermore an experimental analysis of solid waste gasification was conducted using fluidized bed gasifier. In any case, gasification is particularly suitable for homogenous agricultural, industrial waste household waste and fruits waste. And the volume percentage of hydrogen, carbon monoxide, carbon dioxide and methane was calculated on dry, inert free basis and neglecting other gases, which are very low concentrations. The results obtained explained that the hydrogen concentration increase with increases temperature (500 - 800 ^{0}C). Some solid wastes have also comparison as well as, egg cover, household waste, agricultural waste and fruit waste. These are comparison fruit waste more suitable than other. And higher energy source fruit waste. This leads to better yield of hydrogen but much higher steam flow rates will have a contrasting effect on gasification rate because it reduces the reactor temperature. The lower gasification temperature leads to higher char yield, and subsequently results in higher combustor temperature, hotter bed material, and higher gasification temperature, so that less char will be produced.To this end, it is therefore concluded that using a gas engine electricity can be produced from synthesis gas, the composition of different solid wastes can be studied in detail for maximum energy production, and a CFD simulation can be carried out for electricity generation.

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