Studies on Characterization of Sawdust for Application in a Gasification Process for Syngas Production

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Abstract- *Quintessential characteristics of sawdust were investigated in this study as well as to to investigate the ability of reed as a Production of gases via gasification technique by using special gasifier made for this purpose. The physical properties of solid waste results showed that sawdust were suitable for using in production of syngas due to its high volatile matter and cellulose content and low moisture content. The CHNS analysis results showed that high content of hydrogen for sawdust has generated higher amount of syngas heat value, while gravimetric analysis results showed that high cellulose and hemicellulose content gave higher concentration of hydrogen gas. The percentage of production gases was 15.6%, 10.2%, 7.81% and 1.69% for carbon monoxide, carbon dioxide, hydrogen and methane respectively. The effect of operation time on composition of syngas was investigated to generate good quality gas from different types of solid waste. The quality of syngas was started decreasing after about 30 min of gasifier operation. Therefore, each full capacity run should be limited to only 30 min until refeeding is required.*

Keywords- *Gasifire, Sawdust, syngas, biomass materials.*

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1. Introduction

The bioenergy is a living reality, even in its simplest form, especially in rural communities that rely on burning wood and organic waste in cooking, heating and lighting. However, traditional biofuel still supplies about 95% of the energy needs of developing countries, which is a source of energy for about 2.4 billion people. Therefore, the idea of biofuel is not new although the development use and form is striking in the field of sustainable energy [1].

There are two ways to convert solid waste into fuel; where the first method is biochemical, which is achieved by the decomposition of organic matter by organisms. The disadvantages of this method are the requiring expensive enzymes, a large amount of feed preconditioning, and producing a single product (e.g. ethanol) [2,3]. The second way is to convert solid waste into fuel by thermochemical; this method is carried happening by heating the biomass in the presence of steam, oxygen or air to a temperature between 500 and 850ºC. This method is called gasification in case oxygen presence or pyrolysis in the absence of oxygen .High temperature allows breaking of the cellulosic material into a mixture of gases mainly hydrogen and carbon monoxide known as synthesis gas ("syngas").

Gasification is usually defined as the conversion of carbon into gases produced by partial oxidation. The resulting gas is known as syngas, which contains hydrogen and carbon monoxide mainly, as well as methane and carbon dioxide. This gas is later used in more than one field after passing through many processes [4]. Coal is the first material used in the process of gasification but due to demand of sustaining the earth resources, other types of feedstock are being used; which include reeds, corn residues and sawdust...etc. [5].Chemical reaction in the gasification process where some of which are exothermic and some are endothermic [6]. The main advantages of this technique are the low cost of waste used in addition to recycle this waste. Gasification is similar to combustion, but it is considered as partial combustion process, and it has smaller carbon dioxide (greenhouse gas) emission [7].

The objective of study is to use low-cost material to produce syngas as well as Find technique to treatment the solid waste that is attractive both economically and environmentally by Building a system that works on converting solid waste into energy that is in the form of heat or gas.

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2. Materials and Methods

I. Sample Preparation

The sawdust used for this study (It was obtained from a carpentry workshop in Baghdad). It was dried outdoors at an average temperature of about 30∘C to lower its moisture content. This was followed by milling to a size required by the instruments that were used for analyses. The dried and mille sawdust was preserved in a desiccator prior to analyses**.**

II. Proximate Analysis

Information required for moisture, volatile matter, and ash as well as fixed carbon contents of sawdust was given by proximate analysis. These properties are relevant to the thermal conversion of any biomass material into energy [8].

III. Ultimate Analysis

This analysis provided information on the elemental components of sawdust both in qualitative and quantitative terms. A Thermo Quest CHNS elemental analyzer was used for this purpose. The proportion of carbon (C), hydrogen (H), sulfur (S), and nitrogen (N) were determined, while oxygen (O) was obtained by difference.

The energy value, also known as heating value and reported in terms of higher heating value (HHV) of sawdust, was calculated from the mass fractions of the elemental components obtained from CHNS analysis, which was done according to [9].

$$HV\ (MJ/kg) = -1.3675 + 0.3137 \times C + 0.7009 \times H + 0.0318 \times O, \quad (1)$$

Where HV is the heating value measured in MJ/Kg, while C, H, and O are the carbon, hydrogen, and oxygen contents of sawdust.

IV. Thermo gravimetric Analysis (TGA)

The thermal behavior of biomass materials are usually measured by a thermo gravimetric analyzer (TGA), which measures the percentage weight loss of the biomass as a function of temperature and the resulting thermo gram has a peculiar shape for biomass materials [10]. In addition to studying the thermal behavior of Corn Cobs, this analysis was undertaken in order to establish the thermal parameters that would impact on the gasification of the material. It is worth noting that most TGA experiments are conducted under a chemically inactive environment (of which nitrogen or argon is often used) to show the effect of heat degradation that includes carbonization; oxygen is highly reactive and usually not recommended during analyses involving TGA because it reacts with sample components, leading to loss of original sample in the process [10].

V. Fiber analysis

To determine the content of cellulose, hemicellulose, and lignin of solid waste, the gravimetric analysis was carried out according to the method described by previous study [11]. This an importance analysis to obtain information about the effect of structure sample on gasification process.

VI. X-ray diffraction (XRD) analysis

X-ray diffraction techniques are of non-destructive analytical techniques that give information about the crystalline structure, chemical structure, and physical properties of fine materials and layers. These techniques depend on monitoring the scattering of the intensity of a beam of x-ray falling on the sample as a follow-up to the angle of fall and scattering, polarization, wavelength or power. The X-Ray Diffraction technique has been used to examine the structure of crystalline carbon materials such as sawdust, also to understand the change obtained for solid waste ash structure derived from gasification process

3. The Gasifier Model

I. Overview and specifications

The gasifier GEK system (version 4) was constructed from ALL Power Labs Company, and given to the University of Technology by the US Embassy in Baghdad then building in Ministry of Science and Technology, Baghdad. It is essential to work on all the required specifications for gasification systems as shown in Table 1. The GEK Systems are designed for raw biomass and organic based feedstock. Experimental feedstock's lying outside of the suggested ranges may require modification of the equipment and testing of the gas quality produced. The capacity of gases produced by this model is about (2 m^2/1 kg) biomass which produces about 0.75 kWh with biomass consumption rate (kg/hr.) about 12 kg. Dimension of this model is 61 cm height and 43 cm diameter (GEK Experiment).

Table 1: Analysis of physical and chemical properties of the sawdust

Characteristics	Values
Moisture content (dry basis %)	5
Ash content (%)	6.5
Volatile matter content%	74.5
Fixed to carbon content %	11.1
CV(MJ/kg)	18.5
C	46.5
H	6.2
O	40.7

II. Operation of gasifier

After the process of sizing and drying, the raw material was transferred to the reactor through a hole located at the top of the gasifier, and after filling reactor with raw material, the compressor was connected to the reactor through a controlled pipe. Then we burn the reeds by torch with insert a small amount of crude oil to accelerate the ignition, after few minutes. The hot gas exits the reactor and passes through both a cyclone and filter to separate char particulates. The temperature and concentration of gas measured by sensors proposed to this purpose.

4. Results and Discussion

The physical and chemical properties were measurement before gasification process, table below shows properties of sawdust.

From Table 1, moisture content of sawdust was measured as 5%, which is quite different when compared to the values reported in the literature; the difference in these values may be attributed to a number of reasons including the source of the sawdust and handling conditions. The sawdust used for this study is characterized by relatively high volatile matter content (74.5%), which was anticipated because of the organic nature of the material. The contents of volatile matter in biomass materials are usually high due to the organic nature of the biomass, which indicates the biomass potential to create huge amounts of inorganic vapors when used as feedstock in a gasification process; the higher the volatile matter content of biomass, the better its combustion and gasification rates because of the biomass yield upon carbonization [12]. The material is also characterized by high ash content that may also be attributed to a number of factors that include sintering and slagging that may be experienced during gasification, which might also contribute to reduction in process efficiency [13].

The sawdust is composed of three major elements with a higher proportion of oxygen than carbon (Table 1). The content of hydrogen is in agreement with most findings in the literature and had positive contribution to the energy value of sawdust. Oxidation of carbon and hydrogen contents of biomass are usually initiated by exothermic reactions during gasification, forming CO_2 and H_2O, with the CO_2 emitted as a product of complete combustion [10].The relatively low nitrogen and sulfur contents imply lower amounts of NH_3, HCN, and H_2S (which are environmentally harmful compounds) may be anticipated during gasification.

Table 2 shows the results of gravimetric analysis of sawdust. As observed from the results, sawdust had less content of lignin and high content of cellulose. The results are agreement of Safari et al. study [14].

Figure 1 shows the relationship between the weight losses of sawdust as the function of temperature. The plot shows that the thermal degradation behavior of sawdust is characterized by three different weight loss stages with the initial one at 94Cº, which signifies the removal of moisture from the sample. A significant weight loss could be observed between 200 and 500Cºand represents the second stage of the decomposition process of the sample. This may be attributed to the decomposition of basic organic components of sawdust such as cellulose, hemicellulose, and lignin; the decomposition of these components releases volatile gases such as CO_2 and CH_4 that are mainly formed due to the decomposition of hemicellulose between the temperatures of 190 and 320Cº. This degradation temperature for hemicellulose implies less production of tar and char during gasification of sawdust [10]. The third stage of the thermal decomposition process of sawdust is indicated by cellulose and lignin degradation between 280 and 400Cº for cellulose and between 320 and 450Cº for lignin, with total combustion of the sample-taking place as its weight is reduced in the process to give rise to decomposition of hydrocarbons.

The produced gas from gasifier was analyzed by a gas analyzer sensor for sawdust, (figures 2), it can be seen that the concentration of hydrogen was increased with temperature. Conversely, the concentration of methane shows opposite trend. This variation in the concentration of gas may be attributed to Le Chateliers principle [15], which states that high-temperature favorer the reactants in exothermic reactions and products in endothermic reactions.

Where the carbon in solid wastes reacts with oxygen inside the reactor (the oxygen agent supply from the air inlet) resulting in the production of CO gas but with increasing temperature gradually, it is decreasing CO concentration. Hydrogen concentration increased versus decreased concentration of CO and CH_4 with temperature increasing indicate that the CO and CH_4 produced react with the steam (H_2O gas) to produce hydrogen. These results are in agreement with other studies [15,16].

Table 2: The result of gravimetric analysis

Cellulose %	Hemicellulose %	Lignin %
37.8	28	23.4

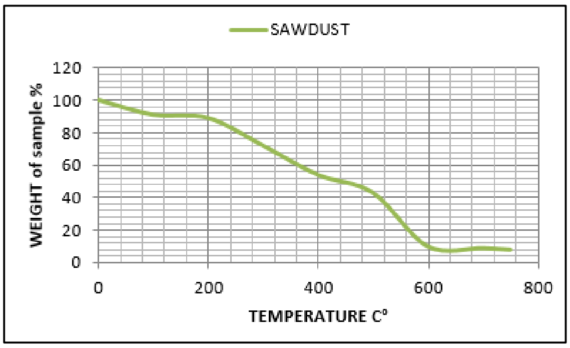

Figure 1: TGA curve of sawdust

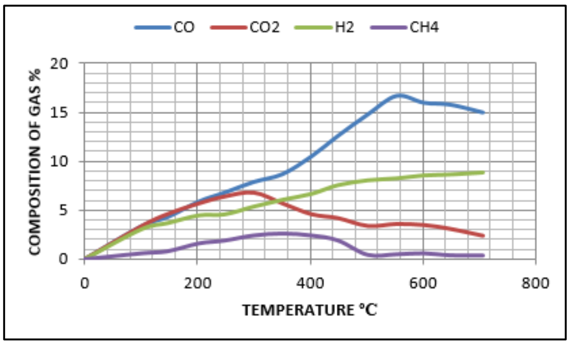

Figure 2: Effect of temperature on gas composition for sawdust

Figure 3 shows the time required for consumption solid waste inside the gasifier. This time starts up from the operation of the gasifier to depletion of feedstock. It is indicative of the end of chemical reactions within the reactor. According to recommended specification, 12 kg of biomass is consumed through one hour. Calculation of time is important in the case of systems that operate in the system of the batch. From figures shown above, it was observed that 5 kg of corn cobs was required 31 min for consumption. The importance of understanding the operation of time in this study in order to calculate the maximum operating time needed the gasifier for the consumption of biomass to stop producing syngas then supplied with fuel in order to keep on the production of gas having good quality. The results are in agreement with study [17].

5. Conclusion

In the current work, the effect of temperature on the composition of syngas generated from sawdust as well as the study of characteristics of raw materials were investigated. The physical properties of solid waste results showed that sawdust were suitable for using in production of syngas due to its high volatile matter and cellulose content and low moisture content. The CHNS analysis results showed that high content of hydrogen for sawdust has generated higher amount of syngas heat value, while gravimetric analysis results showed that high cellulose and hemicellulose content gave higher concentration of hydrogen gas. Thermal behavior of sawdust during gasification had three stages where the first stage demonstrated the removal of moisture content. Decomposition of cellulose, hemicellulose and lignin were occurred in the second stage. While the third stage represented decomposition of the carbonaceous and residuals matter after 400°C. At increased temperature of gasifier, the composition of the hydrogen was increased while that of carbon monoxide concentration was decreased. The effect of operation time on composition of syngas was investigated to generate good quality gas from different types of solid waste. The quality of syngas was started decreasing after about 30 min of gasifier operation. Therefore, each full capacity run should be limited to only 30 min until refeeding is required.

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