P032 - GASIFICATION OF MAIZE COBS AND ITS CHARACTERIZATION FOR ENERGY GENERATION

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ABSTRACT

The gasification of maize cobs and its characterization for its energy potential was carried out. The proximate analysis of the maize cob gave 17.5% moisture content, 1.5% ash content, 73.0% volatile matter, and 8.0% fixed carbon content. A high calculated calorific value of 14.71 MJ/kg was gotten. The exit gas from pyrolysis at 5500C consists of CO, CO_2, H_2, H_2O, CH_4, N_2, and C_2H_6 with percentage composition 7.3%, 11.49%, 0.52%, 4.7%, 4.18%, 3.66%, and, 7.83% respectively. At 700 ºC, the compositions were found to be 8.4%, 13.2%, 0.6%, 5.4%, 4.8%, 4.2%, and 9.0% respectively while 9.49%, 14.91%, 0.68%, 6.1%, 5.42%, 4.74% and 10.17% respectively was obtained for pyrolysis 850ºC. The gasification process revealed that as the temperature was increased more of the biomass was converted to gas leading to less char generation. The result also showed increase in hydrogen, methane, carbon monoxide as well as less desirable carbon dioxide with increase in pyrolysis temperature. The elemental analysis for percentage of carbon, hydrogen, oxygen, nitrogen and sulfur emitted during gasification at 700 ºC for 15 minutes revealed C-78.43%, H-0.64%, O-19.98%, N-0.66%, and S-0.29%. The low amount of sulfur and nitrogen emitted concludes that maize cob can be tapped as a source for energy application. Optimization can be carried out to determine the optimal temperature for high calorific value gas yield.

KEYWORDS

Gasification; Maize Cob; Biomass; Proximate Analysis; Bio-fuel, Syngas

1.0 INTRODUCTION

Despite the advent of renewable energy, a huge amount of man's activities that provide global energy are heavily dependent on fossil fuels, to the degree of 85%. Due to the increase in population, urbanization, and economic growth, the demand for fuel is likely to increase by 50% in 2025 (*1*). The combustion of fossil fuels has led to an ever deterioration of climate due to the increase in greenhouse gases (GHG) which causes global warming and climate change (*2*). Thus, there is a fast-growing emphasis on energy transition and the adoption of renewable energy from biowaste resources which has the prospect of making waste management more efficient and also increasing energy resources in a country like Nigeria (*3*). Therefore, the transition from fossils to other energy sources is increasing renewable energy uptake across the globe. This transition also involves the conversion of waste materials into renewable energy.

The development of alternative recycling facilities, composting, and waste-to-energy in recent years has changed the final destination of these wastes, which is our main concern. Despite this, a sizable portion of the waste produced is still dumped in landfills, where it builds up and negatively impacts the ecosystem. Countries that adopt this policy aim to lessen the environmental issues connected to landfills, such as soil pollution and usage (*4*), leachate contamination of groundwater resources, greenhouse gas emissions from landfill gases, and so on. The production of biomaterials; such as the fractionation of lignocellulosic biomass from forestry and agricultural activities, as well as incineration, anaerobic digestion, pyrolysis, and thermal gasification using wastes as feedstock, have all been explored as alternatives to valorize the wastes produced (*5-7*).

Nigeria has a large quantity of biomass waste generated each year. The effect this waste has on humans and the environment poses a serious threat

(*8*). Biomass such as corn cobs is discarded after the kernel is removed. These widely available corn cobs in Nigeria can be characterized and evaluated for potential energy generation (*8*). Open burning of organics has been widely used in most communities in Nigeria which contributes to the greenhouse effect. (*9*), Hence the purpose of this study is to tap the potential of energy generation of biomasses. Thermal gasification has been employed among all the methods used in WtE facilities to valorize solid wastes, generating heat and syngas. Carbon monoxide (CO), hydrogen (H_2), nitrogen (N_2), carbon dioxide (CO_2), and light hydrocarbons (such as CH_4, C_2H_4, and C_2H_6) are the major components of syngas, a gaseous product that can be used as fuel.

Gasification has utilized a variety of raw materials over the years, including coal and biomass, which are generally feedstocks with a homogeneous composition. Due to their heterogeneous composition, using valorizing wastes, especially industrial wastes, in gasification might be difficult (*10*). This is why in this study, we have focused on biomass (maize cobs) with the aim of pyrolyzing and characterizing them, for energy generation.

This research aims to evaluate the potential of the biomass (maize cobs) for energy conversion; this will be achieved by determining the proximate analysis, ultimate analysis and the calorific value of the maize cob.

2.0 MATERIALS AND METHODS

2.1 Materials

Miller (Thomas Wiley Mill-Model ED5), 2mm stainless steel sieve, Triple beam weigh balance, Gallenkamp oven and furnace, desiccator, crucible, spatula, and corn hub. All analyses were conducted at the National Cereals Research Institute (NCRI) in Badeggi, Niger State.

2.2 Methods

2.2.1 Pretreatment and Gasification of Maize Cob

The corn cob used as biomass was obtained from Gidan Kwanu in Minna, Niger State. Initial size reduction was carried out on the corn cobs using a mortar and pestle. After preliminary size reduction, the corn cob was fed into the miller where it was ground and sieved to a mesh size of 2mm. 2 grams of ground maize cobs were loaded into the furnace. Before pyrolysis, the reactor was purged with inert nitrogen gas to remove any residual air and create an oxygen-free environment.

The temperature of the furnace was raised gradually at a rate of 200C/min from ambient temperature. The maize cob samples were subjected to pyrolysis using ASTM standard method. Evolved gasses (syngas and volatiles) were analyzed for characterization.

2.2.2 Proximate Analysis

This analysis involved the determination of moisture content, fixed carbon, volatile matter and Ash content.

2.2.2.1 Moisture Content

The moisture content of a biomass is the quantity of water per unit mass of a dry biomass. It was done experimentally using the ASTM method of determining the moisture content of the biomass (*8*). The experiment was carried out by weighing an empty crucible, after which 2g of corn cob was added and distributed evenly by tapping the crucible lightly. The crucible containing the corn cobs was then placed in an oven at a temperature (of 105 ºC) for one hour. On cooling, the crucible was weighed, together with the sample. The percentage moisture content was calculated:

$$\textit{Moisture content}\ (\%) = 100\frac{(\boldsymbol{B-C})-(\boldsymbol{C-A})}{(\boldsymbol{B-A})} \quad . \ . \ . \ . \ . \ . \ . \ (1)$$

Where: A = weight of crucible (g), B = weight crucible + wet sample (g), C = weight of crucible + dry sample (g).

2.2.2.2 Ash Content Analysis

Ash content indicates the amount of inorganic matter or components left in the corn cob biomass after combustion. The determination of ash content in the corn cob was carried out using ASTM standard procedure by adding 2 g of corn cob after which the crucible was reweighed again with the sample in it. The crucible was placed in a furnace and allowed to heat at a temperature of 550ºC with the sample in it, for one hour. This was to allow the combustible material not to burn completely. At room temperature, the crucible containing the sample was removed and reweighed.

The percentage was calculated according to the following equation:

$Ash\ content\ (\%) = 100\frac{A-B}{C}$ . . . . . (2)

Where:

A = weight of crucible with sample (g) B = weight of crucible with ash (g)

C = weight of sample (g)

2.2.2.3 Volatile Matter Content Analysis

The essence of volatile analysis is to give a measure of the gasses that were emitted during the thermal decomposition of the biomass in an inert

The fixed carbon of the biomass was computed using the relationship below (Jigisha et al, 2006):

FC=100 - %ASH - %VM - %MC. . . . . (3)

Where

FC=fixed carbon; %Ash=% ash content and %VM=% volatile matter; % MC= percentage

moisture content.

2.3 Ultimate Analysis

The ultimate analysis was carried out to know the elemental composition of the biomass. These elements present in biomass include carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulfur (S). The elemental analysis of the maize cob was carried out using the ASTM standard procedure.

environment. The crucible was weighed and 2 g of corn cob was added, then the new weight of the crucible was measured. The corn cob was spread evenly in the crucible, which was then covered and placed in a furnace that was preheated already to a temperature of 950 ^{o}C for about seven minutes (*11*). The crucible was removed and cooled in a desiccator, then reweighed. The percentage volatile can also be calculated using the equation (*12*).

%VM= [($inital\ weight - final\ weight$)] × 100

2.2.2.4 Fixed Carbon

The Carbon and hydrogen percentage was determined using the ASTM E777 procedure while the Nitrogen and Sulfur was determined using ASTM E778 and 775 respectively.

The Oxygen composition was obtained from the percentage difference of other elements using the equation below [19].

Oxygen composition = 100 – (%S +%N + %H + %O) . . . . . (4)

2.3.1 Heating (Calorific) Value

The net calorific value was determined by using the relationship below:

$CV = 18.7\ (1.0 - AC - MC) - (2.5MC)$ . . . . (5)

Where: CV= lower calorific value; MC = moisture content; AC= ash content

3.0 RESULTS AND DISCUSSION

3.1 Proximate Analysis of Maize Cob Biomass

Table 3.1: The Proximate Analysis (%) and Calorific Values (MJ/Kg) of Maize Cobs

EXPERIMENTAL VALUES (%)	
ANALYSIS	MAIZE COBS
Moisture Content	17.5
Ash Content	1.5
Volatile Content	73.0
Fixed Carbon	8.0
Calorific Value	14.7

3.2 Ultimate Analysis of Biomass

Table 3.2: The Composition of Different Samples after Complete Combustion

SAMPLES	CARBON	NITROGEN	HYDROGEN	SULFUR	OXYGEN
Maize cobs	78.43	0.64	19.98	0.66	0.29

3.3 Analysis of Exit Gas of Maize Cobs

Table 3.3: The percentage composition of compounds in the gas stream at 550°C

COMPOUND	%VALUE
CO	7.33
CO_2	11.49
H_2	0.52
H_2O	4.70
CH_4	4.18
N_2	3.66
C_2H_6	7.83

3.4 DISCUSSION OF RESULTS

The moisture content was calculated to be 17.5%. This is not high, since standards revealed that the suitable moisture content for biomass for biofuels should be less than 20%. The result is higher than those obtained by Ayodele (*13*), and those reported by Maj et al. (*14*). The difference in these values could be due to many reasons; including the source of Maize Cob and processing conditions. A higher moisture content is not desirable due to corrosion concerns. Ash content was determined to be 1.5 %, which is relatively low. The ash content of Maize Cob describes the inorganic matter that is left after the complete combustion of the biomass. This ash contains several elements which may not completely undergo combustion.

Maize Cob was also characterized by a volatile matter content of 73%, which was anticipated because of the organic nature of the material. Volatile matter contents in biomass are usually high because it indicates its potential to create huge amounts of inorganic vapours when used as feedstock in a gasification process. The higher the volatile matter content, the better its combustion and gasification rates because of the biomass yield upon carbonization (*14*). The fixed carbon content was determined to be 8.0 % which represents the percentage of carbon available for char combustion. This low fixed carbon-releasing content causes the biomass to have a prolonged heating time. The solid combustible residue that had its volatiles given off was observed to be low due to its low fixed carbon.

The calorific value obtained was 14.7 MJ/Kg which is slightly less than most values obtained from literature. Those obtained by Maj et al. (*14*) fell between 9.69MJ/Kg to 14.94 MJ/Kg. Our result obtained was also less than those obtained for agro-biomass obtained by Kang et al. (*15*).

Table 3.2 presents the results obtained from the ultimate analysis of maize cob. This analysis is very important because the chemical characteristics of Maize Cobs can also influence the biomass fuel and the operating conditions of the gasifier. The percentage compositions were observed to be 78.4% carbon, 19.98% hydrogen, 0.66% sulfur, 0.64% nitrogen and 0.29% oxygen. The carbon content was observed to be very high due to the cellulosic nature of the maize cobs. Biomass material contains hydrogen in the form of water, and the low hydrogen content was a result of the biomass being dried and stored well before use. The hydrogen content was also low due to the hydrocarbons emitted during combustion. The low oxygen content is due to the presence of oxygen in the form of moisture in the biomass; however, the biomass was combusted in the absence of oxygen and oxygen is contained in the water molecules of the biomass alone. Maize cob was observed to contain low sulfur and nitrogen percentage from the result of analysis carried out which is an advantage for the biomass. These elements are potential pollutants and have the tendency to contaminate the environment and are hazardous to living things in the environment when combusted. This low sulfur and nitrogen is an advantage that maize cob could be blended with other potential solid fuels to reduce the sulfur content of those fuels (*13*).

According to Table 3.3, our major concerns were in the amount of CO and CO_2 released by the biomass. CO and CO_2 values of 7.33% and 11.49% were observed respectively. High composition of CO and CO_2 can cause harm to the environment during combustion; thus, it is important to seek a suitable technology that would optimize this process. These potential pollutants can be reduced by blending maize cob with other fuels like coal with a lower percentage of carbon dioxide and nitrogen emissions.

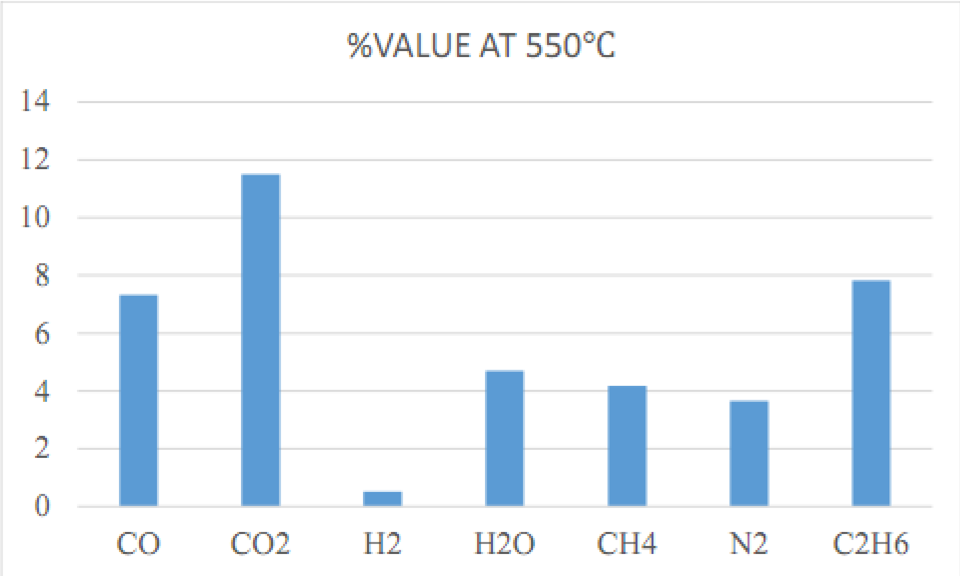

Figure 1: Chart for the percentage composition of compounds

4.0 CONCLUSION

From the above results and discussions, we can thus infer that the use of more optimized technologies for gasification can yield accurate results which will be useful for application in energy generation. The pyrolysis of maize cob has a great tendency to greatly improve the heating value for effective utilization of their biomass in energy conversions. The exit gas from the furnace was characterized by the compositions present in the stream. This is because most of the biomass is volatilized and produces gasses which are essential in power generation. Hence, this biomass can be used as a source of fuel and power generation.

5.0 REFERENCES

1. A. A. Sokan-Adeaga, G. R. Ana, A comprehensive review of biomass resources and biofuel production in Nigeria: potential and prospects. *Reviews on Environmental Health* **30**, 143-162 (2015).
2. Z. A. Elum, D. M. Modise, G. Nhamo, Climate change mitigation: the potential of agriculture as a renewable energy source in Nigeria. *Environmental Science and Pollution Research* **24**, 3260-3273 (2017).
3. R. Ibikunle, I. Titiladunayo, S. Dahunsi, E. Akeju, C. Osueke, Characterization and projection of dry season municipal solid waste for energy production in Ilorin metropolis, Nigeria. *Waste Management & Research* **39**, 1048-1057 (2021).

4. Y. Van Fan, J. J. Klemeš, C. T. Lee, S. Perry, Anaerobic digestion of municipal solid waste: Energy and carbon emission footprint. *Journal of environmental management* **223**, 888-897 (2018).
5. H. Mahmudul, M. Rasul, D. Akbar, R. Narayanan, M. Mofijur, Food waste as a source of sustainable energy: Technical, economical, environmental and regulatory feasibility analysis. *Renewable and Sustainable Energy Reviews* **166**, 112577 (2022).
6. H. K. Jeswani, A. Azapagic, Assessing the environmental sustainability of energy recovery from municipal solid waste in the UK. *Waste Management* **50**, 346-363 (2016).
7. M. Ram, J. C. Osorio-Aravena, A. Aghahosseini, D. Bogdanov, C. Breyer, Job creation during a climate compliant global energy transition across the power, heat, transport, and desalination sectors by 2050. *Energy* **238**, 121690 (2022).
8. C. Ibeto, J. Ayodele, C. Anyanwu, Evaluation of pollution potentials and fuel properties of nigerian sub-bituminous coal and its blends with biomass. *J. Mater. Environ. Sci* **7**, 2929-2937 (2016).
9. O. S. Anuge, A. Ghosh, K. T. W. Ng, in *Canadian Society of Civil Engineering Annual Conference*. (Springer, 2021), pp. 163-171.
10. O. Alves *et al.*, Techno-economic study for a gasification plant processing residues of sewage sludge and solid recovered fuels. *Waste Management* **131**, 148-162 (2021).
11. A. Kwaghger, L. Enyejoh, H. Iortyer, The development of equations for estimating high heating values from proximate and ultimate analysis for some selected indigenous fuel woods. *European Journal of Engineering and Technology Vol* **5**, (2017).
12. Marquez-Montesino *et al.*, Study of the energetic potential of pine biomass Caribea *Revista Chapingo Cien-Cias Foreatale y dei ambient* **7(1)**, 83-89 (2001).
13. J. A. Ayodele, Evaluation of the fuel properties and thermal efficiency of sub-

bituminous coal-biomass blend. *Researchgate*, (2014).
14. G. Maj *et al.*, Energy and emission characteristics of biowaste from the corn grain drying process. *Energies* **12**, 4383 (2019).
15. S. B. Kang, H. Y. Oh, J. J. Kim, K. S. Choi, Characteristics of spent coffee ground as a fuel and combustion test in a small boiler (6.5 kW). *Renewable Energy* **113**, 1208-1214 (2017).