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# A Study of Thermal Energy Potential of Groundnut Shell Gasification for Small -scale Industrial Application.

[1]Kyauta, E.E. [1]Adisa, A.B., [2]Habou, D. &[1]Ejilah, R.I. and [3]Japhet J.A
*[1]Department of Mechanical/Production Engineering.[2]Automobile Engineering Department.*
*Abubakar Tafawa Balewa University, Bauchi.*
*[3]Mechanical Engineering Department,University of Jos*

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**ABSTRACT:**
The threat of fossil fuel depletion and greenhouse gas emission lend credence to the argument that fossil fuels are no longer sustainable for wide use. Environmental concerns as well as dwindling oil resources brought about increasing interest in renewable energy sources. The demand for alternative energy resources that is sustainable for use, environmentally friendly as well as regionally available has been a great challenge for researchers. Therefore, the use of biomass to generate heat energy is crucial in achieving energy independence. In this study, groundnut shell energy potential for small scale industrial application was investigated. A closed top throatless downdraft gasifier was adopted for suitable use in view of the characteristics of the feedstock. It was observed from the findings, that the intensity of the syngas production depend on the volume of air supply, and seen to also affect the biomass fuel combustion and the flame stability. A higher temperature of 1,350 $^{o}$C was attained, and observed to be sufficient for the thermal energy required for firing a baker oven. The quantity of CO and $H_2S$ emitted during syngas combustion is very, low and falls within the WHO safe standard. This confirmed that during the combustion of syngas the emission left are very tolerable as its effects on the environment is likely to be minimal.

**KEYWORDS:** Biomass, Groundnut shell, Gasification, Downdraft gasifier, heating value,

## I. INTRODUCTION

Current energy supplies in the world are dominated by fossil fuels (petroleum, coal andNatural gas) which contributes to about 85% of the total energy demand globally. However, these continuous growth in demand is being confronted with the challenge of fossil fuel depletion and rise of greenhouse emission ($CO_2$), and many other energy-related problems. This challenge provides the motivation to search for non-conventional energy sources, such as; biomass energy. Bioenergy has been observed to have high potential of contributing to energy needs of modern society and it is expected to increase to 14% by 2035 (IEA, 2012). All nations' future economic growth greatly depends on long-term availability of energy from sources that are affordable, accessible and environmentally friendly. (Rachandra and Boucar, 2011). But the energy sector is confronted with immense challenges globally due to increase in energy consumption and the decrease in availability (Rai, 2004).

Electricity as the most widely used and desirable form of energy worldwide, has the basicrequirement for economic growth, national development and adequate standard of living.

Unfortunately, Nigerian electricity supply system which is an interconnected national grid system has been epileptic and has impacted negatively in the performance of small-scale enterprises. (Ekpo, 2009).

According to IEA, (2012) and Ahmed and Mallo, (2015) poor electricity from the nationalgrid is a major constrain to small- scale business in Nigeria. Several researchers have reported that most of the small-scale business operators invest on alternative source of energy to make up for the shortfall in electricity supply. The privatization of electricity is likely to make the rural areas unattractive to private investors due to low consumption rate, and purchase power potential. Such areas may remain unserved for the distant future except an alternative source of energy that is not grid-dependent is explored.(Sambo, 2009). This has further compelled other firms and commercial enterprises to depend on back-up diesel and petrol generators, hence, exposing users to noxious gas inhalation and even death. (Akinbami, 2001).

Small-scale machineries, such as; roasters, kilns, and ovens employ traditional firing systems composed of open fires operated by direct combustion which are mostly inefficient. This inefficient use of energy sources also results in high operational costs thereby leading to low profit margins, as a result of which most of the enterprises are pushed out of business, as costs of production render their products too expensive to compete favorably with similar products in the markets (Mutyaba, 2014). Globally biomass has been acknowledged to be a positive alternative source of energy because it is renewable, cheap, readily available and carbon neutral. Unlike other renewable energy sources, such as; solar and wind, biomass can be converted into various fuel forms (solid, liquid, and gas) through many conversion technologies (Nzila*et al*, 2010).

Among the various biomass conversion technologies in use today, biomass gasification is considered tobe a more suitable technology for crop residue biomass, for reasons that, it offers high thermal efficiency and environmental acceptability. Gasification possesses a considerable potential and can act as an enabling technology for the development of integrated and flexible bio-energy strategies (Tippayawong*et al*, 2011, Scarlat, *et al* 2010). Gasification can be considered an attractive energy option due to abundant availability of feedstock, ease of operation, eco-friendliness and better process control. The downdraft gasifier is also more acceptable worldwide because of its suitability in producing energy at affordable prices in small scale applications. It is comparatively cheaper, and it produces relatively low tar during gasification (Erlic and Frasson, 2011).

The objective of this study is to investigate how gasification technology will be used to reconcile the yawning gap between energy demand and supply, and also address environmental concerns and the challenge of production cost in the small-scale entrepreneurs in Nigeria in the study area.

## II. LITERATURE REVIEW

In Nigeria, priority attention has been given to electricity, gas and conventional fuels for small scaleenterprises and not much activity has been observed regarding the use of biomass. Biomass is a renewable energy source. It is most often referred to as plants or plant -based material that are not used for food (Mohammed, 2014). Large quantities of agricultural residues biomass produced annually worldwide are vastly underutilized (Bhavanam and Sastry, 2011). In the United States, the total primary energy consumption from various biomass resources is currently 4%, and there is an anticipated increase to 10% by the year 2035 (Wenjia, 2013). A major successful use of biomass has been the production of substitute fuels for thermal energy. (Basu, 2013).The total agricultural land available is a measure of biomass potential. Nigeria is blessedwith vast biomass resources that can be harnessed for energy applications. (Mohammed 2012). The use of these biomass for syngas production poses less threat to food security and forest preservation, hence are found suitable and viable for use as gasification feedstock. The pursuit of food and energy security has made tons of residual biomass resources readily available. The production of energy from biomass has the potential to reduce the dependence of developing countries on fossil fuels. (Bridgewater, 2003). The direct combustion of biomass is the most direct and technically easier process but the overall efficiency is low with very high emissions. Therefore, thermochemical conversion (gasification) has an advantage over other conversion technologies because thermochemical process can convert any type of biomass including agricultural residues.
Gasification of biomass can extract up to 60 -90% of the energy stored in biomass and can be used as a source of energy in rural and off-grid areas to fill the energy gaps( Kumar *et al* 2018; Asmadullah, 2014).

Kuheand Aiyu(2015) carried out an experimental investigation of biomass gasification in a closed-top throatless downdraft gasifier using groundnut shells as fuel. The result shows that groundnut shells was successfully used as feedstock and can be used as a source of clean fuel for rural communities in Nigeria.

Godwin *et al*, (2016), conducted another test with a downdraft gasifier using a corn plantation wastes blended with suitable agents to provide continuous burning. Gasification and corresponding thermal conversion efficiency of corn biomass fuel was found to be around 65% with a heating value of fuel 4.2MJ/m. It was observed that the biomass of lighter weight was better for feeding the gasification system.

In another related study, Panwar*et al* (2009) reported that biomass fuels continue to play an important role in thedomestic and industrial sectors in India, as it is an agricultural-based economy. The substitution of conventional fossil fuels with biomass for energy production results both in a net reduction of greenhouse gases emission and in the replacement of non-renewable. In same vein, Virmond*et al*. (2013) studiedthe effect of size and shape of feedstock on efficiency indifferent types of reactors. It was concluded that finer and low-density feedstock tend to exhibit bridging problems especially, in the throated gasifiers but modified throatless gasifiers are suitable for unrestricted movement of such feedstock.

Barrio *et al*. (2009), modified air distribution system and injected air at the center of the reactor cross section so that air was distributed uniformly to all sides of the reactor. Perforated grate with manual actuation was also introduced and used to clear the ash contents continuously and to ensure smoother bed movement.

Chowdhury *et al (*2011) reported that the thermal efficiency of a 6-7 kW downdraft biomass gasifier developedand tested at Durham University, UK., was found to be 90.1- 92.4%. The temperature inside the reaction zone was (950-1150) °C, with a primary airflow rate of 0.0015 m3/s and syngas exit temperature of 180-220°C respectively.

Furthermore, Palit and Mande (2007) reported that various biomass gasifier designs (downdraft, updraft, and natural draft) for thermal applications for over two decades, and more than 350 TERI gasifier systems have been successfully installed throughout India. The collective installed capacity is over 13MWth. Hence, the foregoing citations, provides compelling body of argument that biomass gasification designs and applications are common place in many climes of the world, and can also be suitably deployed for thermal energy generation for small-scale industries in Nigeria

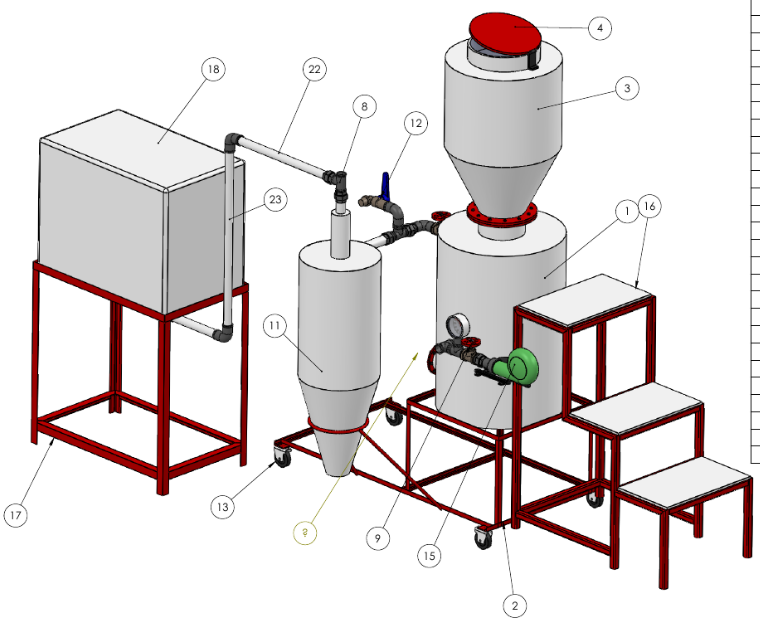
## III. MATERIALS AND METHODS

The groundnut shell was collected from the machineprocessing centers in the study area and manuallyprocessed. The materials were sun -dried to reduce the moisture content of the feedstock.

### 3.1. The gasifier details.

The fixed bed downdraft gasifier(refer to Figure 1). employed for this study was designed and constructed by at the Center for Industrial Studies (CIS), Abubakar Tafawa Balewa University, Bauchi-Nigeria. The reactor is made from a 150mm diameter mild steel of 8mm thickness, which is inserted in external cylinder of 550mm diameter with a critical height of 798mm.

It consists of steel grate, air inlet port of 25mm located 10mm above the grate. While the gas exit pipe is located at the top of the reactor about 650mm from the base of the reactor. It also consists of an air blower assembly, and a char chamber. The grate placed in the reactor holds the biomass but allows the ashes to fall freely into the ash chamber.




| ITEM NO. | PART NUMBER | QTY. |
|---|---|---|
| 1 | Barrel | 1 |
| 2 | Barrel Support | 1 |
| 3 | Hopper | 1 |
| 4 | Cover | 1 |
| 5 | Exhaust | 1 |
| 6 | Elbow | 5 |
| 7 | screw | 20 |
| 8 | T Joint | 6 |
| 9 | Screw Valve | 2 |
| 10 | Joint | 5 |
| 11 | Cyclone | 1 |
| 12 | Tap | 1 |
| 13 | Roller | 4 |
| 14 | Wheel | 4 |
| 15 | Air Pump | 1 |
| 16 | Stairs | 1 |
| 17 | Oven Stand | 1 |
| 18 | Oven | 1 |
| 19 | Cover 1 | 1 |
| 20 | Cover 2 | 1 |
| 21 | Cover 3 | 1 |
| 22 | Pipe 1 | 1 |
| 23 | Pipe 2 | 1 |
| 24 | Pipe 3 | 1 |
| 25 | Burner | 1 |
| 26 | Pressure Gauge | 1 |
| 27 | Step | 3 |

**Figure1.** Orthographic view of gasification plant Assembly

### 3.2. Systems Operations.

A multi-gas monitor model T40 with the following technical specification (refer to table 1) was used to monitor the syngas characteristics. The composition of the syngas both before and during combustion was determined. The fuel consumption rate (FCR) was measured by charging the gasifier with a known quantity of feedstock while the time it takes to completely burned was measured.A weighing balance was used to manually measure the required quantity of biomass fuel.

The feeding of the gasifier was done through the hopper opening and subsequently covered. After loading the feedstock, a paper soaked with a small quantity of kerosene was inserted through the ignition port. It was then ignited with a natural gas lighter with sufficient air supplied from the air blower to initiate and sustain combustion.

The syngas produced was ignited while the characteristics of the gas and flame were observed. The consumption rate of biomass was also calculated. The hot producer gas generated is drawn below the grate and then moves upwards through the annulus of the reactor, where a part of the heat of the gas is transferred to the cold biomass feedstock entering the reactor from the hopper. This allows the syngas to preheat and dry the feedstock. For evaluation of the performance of a gasifier system for thermal application the following parameters were determined, fuel consumption rate, flame temperature, gas outlet temperature and air flow rate. Other instruments used for this research are infrared thermometer, stop watch, digital weighing balance and anemometer to measure gas and syngas flowrate.

## IV. RESULTS AND DISCUSSION.

### 4.1. Syngas Generation.

The feedstocks employed in this study was groundnut shells. Groundnut shell (GNS) has a heating value that is nearly equal to that of wood but physical properties like low density and poor material flow characteristics lead to problems in its processing in a gasifier as reported by (Gold and Seuring 2011). But these problems wereminimized in this study. Its ash content is also found to be very low, reducing the need for frequent removal of ash and the possibility of the occurrence of clinkering and slagging. It was observed that groundnut shell generates the combustible gas after 5 minutes of operations. The results of the gasifier operation parametersare as shown in table 1. The combustion rate of the feedstocks was found to be 100g/min with air flow rate of 3.6m/s as reported in the literature. The syngas exit temperature was found to be within the range of 92 – 105 $^{o}$C. A full load of biomass in the gasifier hopper generated combustible gases and run for about 4 hours. It was observed that the intensity of the syngas production depends on volume of air supply and also affects the combustion and the flamestability. So proper control of air supply was required to maintain stable combustible gas production.

The recirculation of syngas was successful due to the use of air blower. The syngas recirculation also helps in preheating the gasification agent and feedstock as reported by Akinola and Fapetu (2015) who achieved higher efficiency by allowing air distribution and recirculating the syngas within the reactor. The syngas recirculation allows movement over the feedstock as it flows from the gasifier to the hopper. This also is the reason for the low syngas exit temperature since some of the heat was given out in feedstock drying.

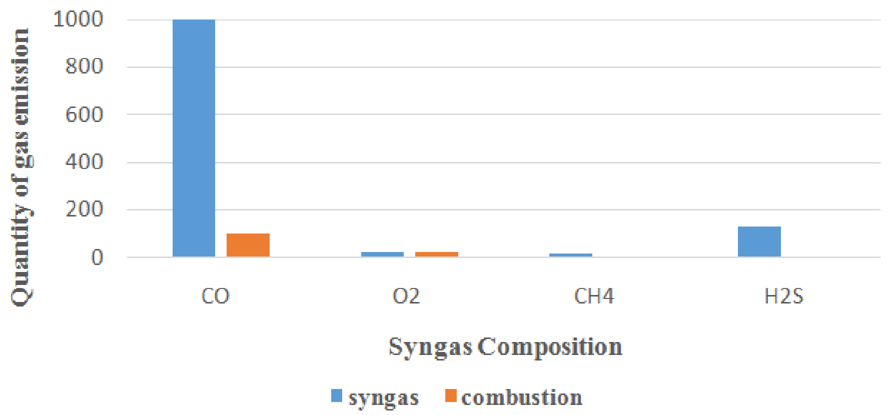



Figure 2. Result of syngas emission Analysis.

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**Table 1. Results of groundnut shell gasification parameters**

| | |
|---|---|
| Air flow rate | 3.6 m/s. |
| Reactor Temperature | 289$^{o}$C - 544.8$^{o}$C |
| Syngas Temperature | 92 - 105.3$^{o}$C |
| Flame Temperature | 1,375$^{o}$C |
| Combustion Time | 100g/minutes |
| Gas flowrate | 0.4m/s |

**4.3. Syngas Combustion.**

The syngas produced was ignited and the characteristics of the gas, flame and biomass was observed. A complete combustion of syngas was achieved by using the fabricated burner The results of the gas and combustion analysis in Figure 2 represents the quality of gas generation and it also serve as an evidence representing the minimal quantity of CO and $H_2S$ emitted during syngas combustion and their values unarguably, falls within the WHO standard. Hence, it further goes to confirm that noxious emission generated during the combustion of syngas are minimal and not likely to adversely affect human lives and the environment.

The flame as shown in Plate 1.represents the various operating conditions of the reactor. When sufficient air is supplied, no soot is produced and the flame becomes blue as in Plate 1a. The different flame configuration as shown in (a - c) was based on the variations in feedstock combustion rate and syngas flowrate.As the feedstock decreases in the gasifier the flammable gases in the syngas also decreased, as well as decreased syngas heating value and flame temperature. The variation in the air syngas ratio value also led to reduction in the composition of the flammable gases (CO, $H_2$, $CH_4$), which also affected the quality of the resulting flame which is the reason for the differences in configurations.

The results of the flame temperature of burning syngas as measured using an infrared thermometer was about 1350 $^{o}$C.The intensity of the flame andtemperature decreases as the air flow rate decreases. As the feedstock decreases in the gasifier the flammable gases in the syngas also decreased, as well as decreased syngas heating value and flame temperature.

(a) (b) (c)

**Plate 1. Flame Configuration**

## V. CONCLUSION

Biomass has high potential to contribute to the energy need of modern society. For reasons, that the downdraft gasifiers are comparatively easy to build with low cost materials, makes it an attractive technology for thermal application. Hence, the following could be concluded from the study.

i. The potential use of loose groundnut shells as replacement fuel for wood and briquetted biomass in fixed-bed downdraft gasification is being demonstrated in this research.
ii. The study has shown that the biomass gasification of agricultural residues can be achieved in a throatless fixed-bed downdraft gasifier with minimal flow problems.
iii. It could also be seen that no further energy input to densify into briquettes or pellets is required to achieve high combustion temperature.
iv. The modification of thegasification procession the feeding of feedstock, air supply and recirculating system enhances the performance of the gasifier. Consequently, a flame

temperature of 1,350°C was obtained and minimal noxious emission levels was recorded during combustion of syngas, and this further recommended the usability groundnut shells in a throatless fixed-bed downdraft gasifier for small-scale thermal applications.

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