Journal of Basics and Applied Sciences Research (JOBASR)
ISSN (print): 3026-9091, ISSN (online): 1597-9962
Volume 2(2) June 2024
DOI: https://doi.org/10.33003/jobasr-2024-v2i2-56

Assessing the Performance of Treated Biogas and Petrol-Powered Generators: A Comparative Analysis for Energy Efficiency

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ABSTRACT
The gas was then compressed in a cylinder with the aid of a pressure valve and refrigerator compressor, a 3kg cylinder was used and the pressure was observed with the aid of pressure valve. A 5.5KW generator was used the carburetor was replaced with a low pressured hybrid carburetor. The biogas was then connected to the carburetor and the generator works smoothly without any sign of knocking, the power output was evaluated using 200W incandescent bulbs and was evaluated at 200W,400W,600W,800W,1KW,1.4KW. It was observed that 0.5bar of the gas which is approximately 0.4935atmL was used for 60 minutes when the generator operated at 1.4kw compared to petrol which uses 1.5atmL for 60 minutes at the same load condition. It can therefore be concluded that the use of biogas for electricity generation is possible and cheaply compared to petrol. It is however recommended that further research should carried out on the exhaust emission of generator when using biogas, engine speed should be determined, the kinetic studies should be carried out, the shelf life of the engine oil should also be determined.

Keywords:
Biogas, scrubbers, gasoline, generator, energy efficiency

INTRODUCTION

Energy is a vital component of economic growth and development in modern society, with electricity being the cornerstone of the modern economy (Ahlberg-Eliasson et al., 2018; IEA, 2021). Nigeria, the fastest-growing economy in Africa, is rich in fuel resources but faces challenges in electrification and clean energy. Ending energy poverty is a major priority, and addressing this requires leapfrogging energy access.Currently, Nigeria's electricity access rate is around 60% (World Bank, SE4ALL Database Report, 2019), with significant disparities between urban (55%) and rural (41%) areas. Moreover, access to non-solid fuels is limited, at only 4%. To achieve universal access to affordable, reliable, and modern energy by 2030, Nigeria must integrate more renewables into its energy mix and improve energy efficiency. The International Energy Agency (IEA) warns that current policies, combined with fossil fuel depletion, climate change, and rising emissions (IEA, 2021), necessitate alternative approaches to electricity generation. Renewable energy sources, such as photovoltaics, wind turbines, biomass-biofuel, and small hydro plants, offer a sustainable solution and are less vulnerable to energy security concerns (Kabeyi and Olanrewaju, 2020; Kabeyi and Olanrewaju, 2022). Biomass, in particular, can be converted to electricity through combustion, gasification, biological digestion, or fermentation, making it a low-carbon process (Ayuningtyas et al., 2018; Kabeyi and Olanrewaju, 2021; Jeremiah et al., 2022).

MATERIALS AND METHODS

Compression and storage of treated biogas

Compression of the treated (scrubbed) biogas was performed using a reciprocating compressor, similar to those used in commercial refrigeration systems (Akpojaro et al., 2019). The compressor, with a capacity of 1.5 horsepower, is capable of compressing biogas to a maximum pressure of 5 bars. The compression process involves drawing scrubbed biogas into the compressor through an inlet channel, reducing its volume, and increasing its pressure. The compressed biogas is then discharged through an outlet channel into a storage tank (CNG cylinder). To ensure safe operation, the compressor is designed with a suction capability that draws biogas without displacement. Additionally, a pressure gauge is used to monitor and measure the pressure leaving the compressor, preventing potential explosions. By compressing the scrubbed biogas, its energy density is increased, making it suitable for storage and transportation.

Figure 1: Biogas Compression

The Spark Ignition Engine Generator

The gasoline fuel generator (Parsun Gasoline Generator is a single cylinder, 4 – stroke, air cooled spark ignition engine (Figure 2) that was modified by the coupling of a hybrid carburetor to its carburetion unit. The specifications of the generator are contained in table below

Table 1: Specifications of the Generator used

Parameter	Specification
Max power output/frequency	5.5KW
Phase	1
No. of cylinders	Single
No. of stroke	4
Cooling system	Air cooled
Fuel	Petrol
Fuel tank capacity	17L

Figure 2: Showing the parson generator

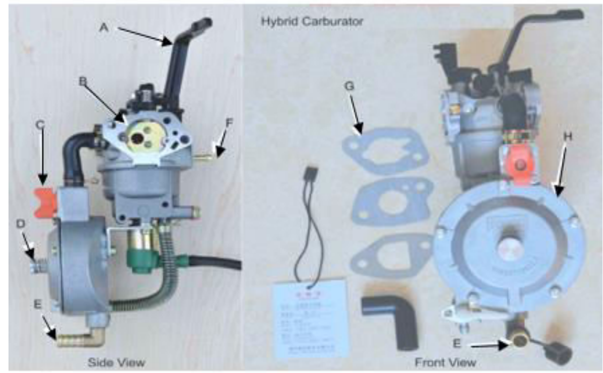

Figure 3: Hybrid Carburetor

A = Choke; B = Gasoline carburetor manifold; C = Switch for gas or gasoline use D = Pressure release valve; E = Gas supply inlet F = Gasoline supply inlet and G = Gas - air mixing chamber

Modified Spark Ignition Biogas Generator

A hybrid dual-fuel carburetor (Figure 4) was integrated into the manifold of the spark ignition engine generator, enabling the use of biogas as a fuel source. This modification allows for seamless switching between biogas and gasoline without requiring additional physical modifications. The hybrid carburetor ensures a smooth supply of biogas, a combustible gaseous fuel at low pressure, to the engine. When the generator is turned on, negative pressure enters the pressure regulating valve via the air/fuel mixer, triggering the sealing arm of the swing valve to open and supply the gaseous fuel. This process enables the engine to operate smoothly. The power generation system consists of a combination of an internal combustion engine (ICN) and a synchronous generator. To generate electrical power output, a low-pressure gas carburetor was incorporated into the ICN, allowing for the combustion of biogas in the combustion chamber. This triggers the engine to produce a torque, rotating the synchronous generator. Notably, modifying the spark engine for biogas utilization requires minimal modifications, as spark ignition engines are originally designed to operate on an air/fuel mixture with spark ignition. The modification process involves adding a methane (biogas)-air mixer to the engine (Okwu *et al.*, 2020; Tagne, 2021).

Figure 4: Modified generator

Conversion of Biogas to Electricity

A hybrid carburetor was used on the generator. It works like any carburetor in a generator with the difference being that this type of carburetor allows one to run a generator with either cooking gas or petrol. A hybrid dual fuel carburetor was attached to the manifold of the spark ignition engine generator to enable the use of biogas as fuel. The hybrid carburetor allows instantaneous switching to gasoline fuel without any other physical modification for the production of electricity. The current and voltage was measured using ammeter and voltmeter respectively. A load was connected to the generator and fuel consumption (Biogas) was measured at different time interval, the overall efficiency of the generator was evaluated.

Figure 5: Modified generator running on biogas with load

Measurement of Power Output of the Generator

To establish a baseline for comparative analysis, the generator was initially operated using petrol. The engine's power output was measured at various load conditions, providing a reference point for subsequent evaluations. Next, biogas was used as the fuel source, and the generator's performance was assessed using a variable electric load consisting of seven 200W incandescent bulbs. The collected data were recorded and compared to the baseline data obtained from petrol operation. The power output of the generator was calculated using the following equation:

$$P = VI \qquad (1)$$

Where P is power output of the generator; V is voltage output of the generator; I is current output of the generator,

This equation allows for the accurate determination of the generator's power output, enabling a comprehensive evaluation of its performance under different fuel sources and load conditions.

RESULTS AND DISCUSSION

Comparative Analysis of Biogas and Petrol Consumption

A comparative analysis of biogas and petrol consumption was conducted, following the methodology outlined by Okwu et al. (2020). The biogas consumption rate was observed with respect to time, and the biogas was measured before and after running the power generating system with a load input of 1400 watts. The biogas was run on the system for 60 minutes, after which it was measured again. To facilitate a direct comparison, petrol was then added to the generator with the same 1400-watt load, and the running time was recorded. To ensure consistency in units, both biogas pressure and petrol volume were converted to Liter-atmospheres (atm. L). This standardized conversion enables a direct comparison of the two fuel sources' consumption rates. The comparative analysis provides valuable insights into the efficiency and performance of biogas and petrol as fuel sources for power generation, allowing for informed decisions on fuel selection and optimization.

Modification of the Generator to Use Biogas

The gasoline generator was modified to operate on biogas by replacing its carburetor with a hybrid carburetor. The scrubbed biogas from the cylinder was connected to the hybrid carburetor, and the generator was started. Initially, the engine was allowed to run for 30 minutes without any load to ensure stable operation. Subsequently, a load was applied using a 200W incandescent bulb, and the current and voltage were measured using a digital multimeter at various load conditions. This step enabled the evaluation of the generator's performance and efficiency under different load scenarios while operating on biogas. The modification and testing process aimed to assess the feasibility and performance of the generator running on biogas, a renewable energy source, and to identify potential areas for optimization.

Electricity Voltage Output and Load Bearing Characteristics

The results on Table 2 showed a comparison of the performance of a modified internal combustion engine running on biogas and petrol at various load conditions

Table 2: Performance Comparison of Treated Biogas and Petrol-Powered Generator

S/NO	Load(Watt)	Voltages(V) Of biogas	Voltages(V) Of Petrol	Current(A) Of Biogas	Current(A) Of Petrol	Power(W) Of Biogas	Power(W) Of Biogas
1.	200	218	222.1	0.87	0.92	189.66	204.33
2.	400	216	220.4	1.83	1.82	395.28	401.13
3.	600	214	217.5	2.71	2.74	579.94	595.95
4.	800	212	215.1	3.58	3.90	758.96	838.89
5.	1000	210	212.2	5.00	5.10	1050.0	1082.22
6.	1200	214	213.0	5.78	5.78	1236.92	1278
7.	1400	216	214.8	6.20	6.20	1339.2	1359.68

The table 2 presents the voltage output and load bearing characteristics of the power generation system, providing valuable insights into its performance and capabilities. The data includes voltage output values at various load conditions, allowing for an assessment of the system's ability to maintain a stable voltage supply under different loads.

The voltage output of the biogas-powered engine is slightly lower than the petrol-powered engine across all load conditions, with a maximum difference of 4.1V (at 200W load). The current drawn by the biogas-powered engine is generally lower than the petrol-powered engine, except at 600W and 1000W loads, where the values are similar. The power output of the biogas-powered engine is lower than the petrol-powered engine at all load conditions, with a maximum difference of 79.93W (at 800W load). The efficiency of the biogas-powered engine can be calculated by comparing the power output to the input energy. Although the exact efficiency values are not provided, the results suggest that the biogas-powered engine may have a slightly lower efficiency than the petrol-powered engine. Both engines demonstrate a stable performance across the load range, with no significant drops in voltage or power output.

Comparative Analysis of Biogas and Petrol Consumption with Load

A comparative analysis of biogas and petrol consumption was conducted under the same load conditions for 60 minutes. The results showed that biogas consumption of 0.5 bar (equivalent to 0.4935 atm. L) for 60 minutes while Petrol consumption of 1.5 litres (equivalent to 1.5 atm. L) for 60 minutes. The analysis reveals that biogas has a longer lasting time compared to petrol under the same load input. Additionally, biogas burns cleaner, releasing less heat than petrol. This suggests that biogas is a more efficient and environmentally friendly fuel source compared to petrol.

CONCLUSION

In conclusion, the comparative analysis of biogas and petrol consumption under the same load conditions for 60 minutes demonstrates the superiority of biogas as a fuel source. Biogas consumes less energy (0.4935 atm. L) compared to petrol (1.5 atm. L) while providing a longer lasting time and cleaner combustion, releasing less heat. These findings suggest that biogas is a more efficient, sustainable, and environmentally friendly alternative to petrol for power generation, making it an attractive option for reducing greenhouse gas emissions and mitigating climate change.

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