International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 7 Issue 1, January-February 2023 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Biogas-Petrol Blend Development and Testing as Alternative Fuel for Spark Ignition Engine

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ABSTRACT

The goal of this study is to create and test a biogas-petrol mixture that can power spark-ignition engines. A biogas: petrol blend with a 20:80 ratio was created as a substitute fuel for spark ignition engines. To evaluate the performance of the fuels, comparison tests using gasoline and a biogas-petrol combination were conducted on the test bed. The experiments' findings demonstrated that the biogas-petroleum blend produced higher torque, brake power, indicated power, brake thermal efficiency, and brake mean effective pressure yet used less fuel and heated the exhaust less than gasoline. According to the study's findings, a biogas-petrol mix spark ignition engine was shown to be cheap, use less fuel, and contribute to sanitation and fertiliser production.

KEYWORDS: *Biogas, biogas-petrol blend, feedstock, fuel consumption, internal combustion engine, spark ignition engine, torque*

How to cite this paper: Prof. Mihir Kumar Pandey | Anil Kumar Dwivedi "Biogas-Petrol Blend Development and Testing as Alternative Fuel for Spark Ignition Engine" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-7 | Issue-1, February 2023, pp.513-522, URL: www.ijtsrd.com/papers/ijtsrd52718.pdf

IJTSRD52718

1. INTRODUCTION

Biogas, unlike fossil fuels, is fundamentally renewable since it is produced from biomass, and this source is effectively a reserve of solar energy via the photosynthesis process. Anaerobic digestion (AD) biogas will not only improve a country's energy basket position, but will also make a significant contribution to natural resource conservation and environmental protection.

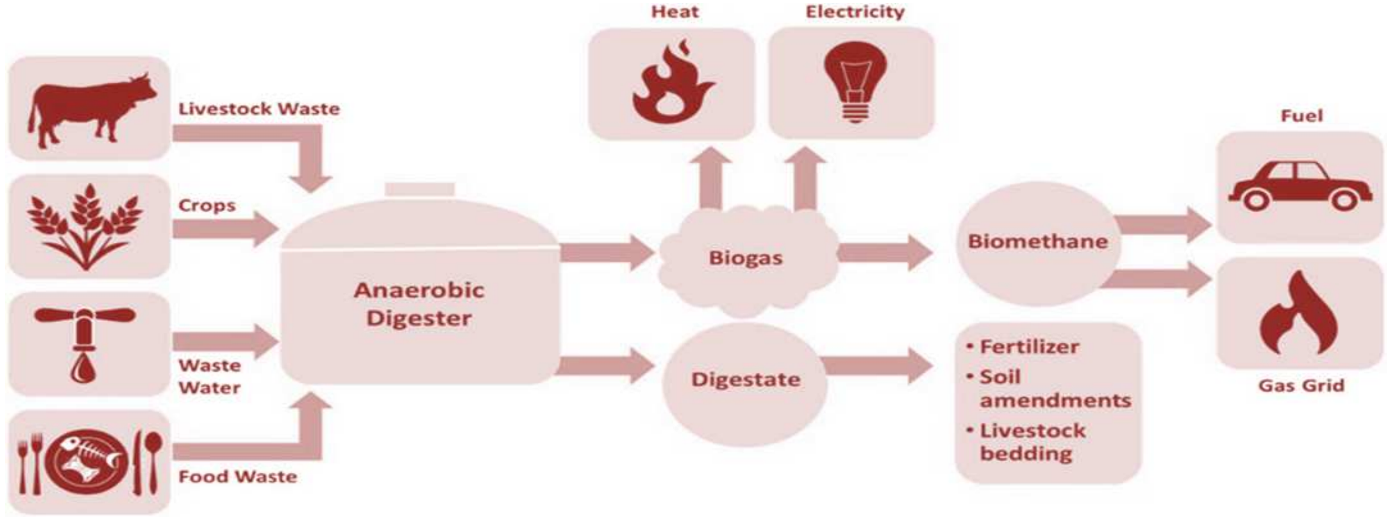

Figure 1 Biogas Production

Biogas is made up of naturally occurring biogenic material. This naturally occurring biogas spreads into the environment, and its main component, methane, has a significant negative impact on global warming (Bochmann and Montgomery 2013). Over the last several decades, methane has been used as an essential fossil fuel and converted to provide electricity, transportation, and heating. Nowadays, natural gas resources account for the majority of methane consumption and usage, although bio-methane generation from waste recovery methods has expanded significantly. Over the last nine years, its manufacturing capacity has increased by 4%. (From 2010 to 2018). Currently, around 3.5 Mtoe of biomethane is generated globally, and the potential for biomethane production today exceeds 700 Mtoe. Of course, this does not imply that methane conversion from all natural resources is practical. In other words, biogas infrastructures rely heavily on specific equipment and the availability of control and management systems.

As a result, a sustainable industry that generates bio-energy from renewable and green natural resources may be constructed and executed.

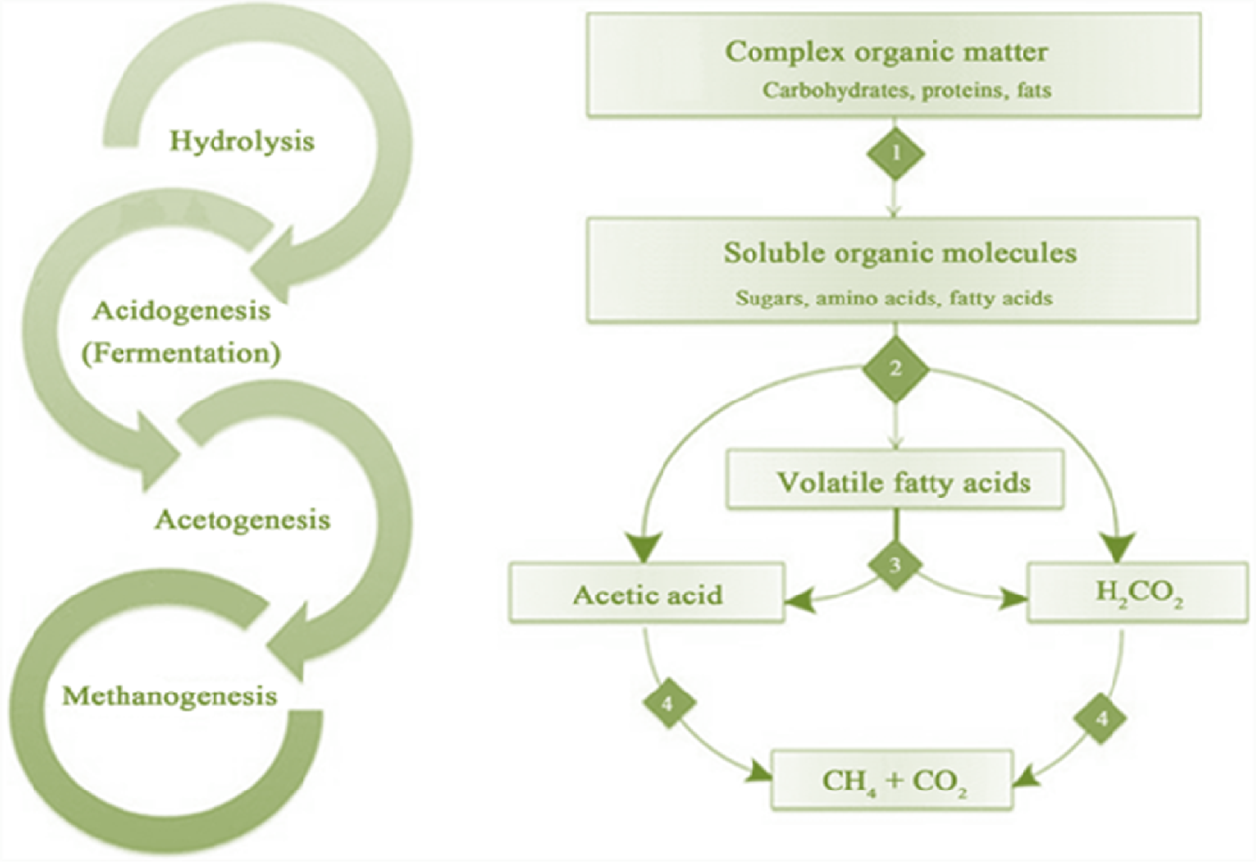

Figure 2 Microbiology of Biogas Production

Concurrent generation of heat and electricity using CHP systems is an operational strategy for improving biogas energy conversion efficiency. Only a small portion of the energy contained in biogas is consumed when converting it to power or heat. Typically, related power conversion productivity in these sorts of systems is between 30 and 40%, but it is reduced when biogas is used as a replacement to refined and simply natural gas. CHP facilities have the benefit of using high-temperature exhaust gas from the electricity production subsystem (ICEs or GTs) as a source of useful heat for many of the previously listed heating needs. Although simple plants' electricity generation efficiency is only 20-45%, a larger portion of energy (around 60% of the utilised energy is converted to heat that is reused by heat recovery systems, making it more appealing when there is a high heat demand. This significantly improves system efficiency and plant payback period, making dispersed generation the most popular biogas use. Extra power might be given to the national grid, while excess heat could be sold for local district use.

A CHP cycle has a high efficiency of up to 90% and may produce 35% and 65% of the produced electricity and heat, respectively. In this situation, some thermal energy is used to heat the process, while approximately two-thirds is used for external purposes. Some proposed models for biogas-based power plants neglect the utilizations of produced heat and focus solely on generating electricity. This strategy has no economic justification and must utilise all of its thermal potential.

As an alternative to fossil natural gas, biogas converted to biomethane (through upgrading and cleaning) may be easily used in natural gas-powered cars. Using biomethane as transportation fuel results in impressively low GHG emissions, making it a viable renewable fuel source. In terms of environmental and economic factors, biomethane appears to be an excellent choice to replace fossil-based fuels. However, when biomethane is used in sophisticated hybrid or fuel cell vehicles (FCVs) instead of existing biodiesel or ethanol-powered ICE vehicles, overall efficiency is much enhanced. In general, biogas may be converted into transportation fuels (bio-CNG) that can be stored for later use, such as liquefied biogas (LBG), syngas/hydrogen, methanol for gasoline synthesis, ethanol, and higher. Compression and liquefaction are prominent physical ways for converting biogas into bio-CNG and LBG, but catalytic reforming is the major chemical method for obtaining syngas. Syngas may be transformed into a range of alcohols such as methanol, ethanol, and butanol via Fischer-Tropsch synthesis (FTS) or fermentation. This alternative fuel has previously been used in the European Union and the United States. In Sweden and Germany, for example, many cars in urban public transportation run on biogas, either as 100% methane (CBG100) or blended with natural gas (e.g., CBG10 and CBG50).

The chemical process for producing biogas is divided into three step:
Stage 1 - The biomass feed in a digester where organic matter containing a complex component (carbohydrates, proteins, and lipids) is hydrolyzed (broken down in the presence of water). Polymer molecules are broken down into little monomer units. These activities are completed in a digester in one or two days at 25 degrees Celsius [4].

Stage 2 - Acid formers are anaerobic bacteria that can thrive without oxygen and create acetic and propionic acids. Carbon dioxide is also emitted at this stage, which takes roughly one day at 25 degrees Celsius.

Stage 3 - During this stage, anaerobic bacteria produce methane, carbon dioxide, and a little amount of hydrogen gas. At 25 degrees Celsius, these processes take roughly two weeks to complete.

2. LITERATURE REVIEW

According to **Vipul Vaid and Shivangi Garg (2017),** biogas is a valuable renewable energy source comprising 55% methane and a sustainable form of waste disposal. It has no geographical boundaries and does not require complex technology to produce energy; it is also very simple to use and deploy but has yet to realise its full potential. These resources, when combined with new and developing conversion technologies and suitable energy policy, have the potential to make biogas a significant contribution to the renewable energy landscape. Biogas may help decentralise energy generation, and the immediate benefit of having a small biogas system is the cost savings over using kerosene or LPG for cooking. Kitchen waste biogas systems are 800 times more efficient than traditional biogas systems. Kitchen trash has a high calorific content and nutritional value to bacteria, which increases the efficiency of methane generation by many orders of magnitude.

Nabila Laskri and Nawel Nedjah (2018) conducted research on two distinct substrates: biodegradable garbage from a landfill and sludge from a wastewater treatment facility using a natural lagoon. They observed the progress of organic matter breakdown in both tests, which were conducted in a one-liter sealed digester. The biogas generated by the anaerobic digestion of the two substrates highly combustible, containing more than 64% CH4. When the volume of biogas created during the digestion of the two substrates of digestion was compared, we discovered that the volume collected from sludge waste is more than ten times more than the volume of biogas produced with organic matter in the landfill. The volume of biogas generated is always a function of digestion residence time and organic matter content in the experiment. The sludge's COD reduction percentage was calculated to be 87.3%.

The anaerobic treatability and methane production potential of three distinct cotton wastes, namely cotton stalks, cotton seed hull, and cotton oil cake, were evaluated in batch reactors by **Iscia and Demirerb (2019).** Furthermore, the effects of nutritional and trace metal supplementation were studied. Biochemical methane potential (BMP) studies were carried out for two distinct waste concentrations, namely 30 and 60 g/l. Cotton waste may be handled aerobically and is an excellent source of biogas, according to the findings. In the presence of basal medium (BM), 1 g of cotton stalks, cotton seed hull, and cotton oil cake generated approximately 65, 86, and 78 ml CH4 in 23 days, respectively. The addition of BM has a very favourable impact on biogas output.

Ezeand Elijah (2020) worked on blending various fuels to run an internal combustion engines. For example, a study of performance and exhaust analysis of petrol engine using methanol-gasoline blends at 2000rpm and variable load condition at various blend condition produces promising brake power, brake specific fuel consumption, brake thermal efficiency and lower fuel consumption when compared with that runs on pure petrol. Carbon monoxide CO, Carbon dioxide CO_2 and Hydro carbon HC emissions also decrease when using a methanol-gasoline blend.

3. METHODOLOGY

3.1. Digester

The digester will ferment the food waste that is present at the hostel mess and on college grounds. The digester is intended to handle a maximum of 250kg of food waste each day. The retention duration is 30 days, and the maximum amount of waster contributed is 100 ltr. The digester has one intake and a crusher (2HP motor) to crush the waste to a size of 5 to 8 mm. The exit is connected to a 4 diameter pipe that will transport the manure.

Figure 3 Biogas Digester and Crusher

3.2. Floater

The floater collects the biogas produced by the fermentation of food inside the digester. The floater is also known as the digester's floating dome. It collects the bio gas created as a result of anaerobic fermentation of food waste. As the gas is created, the dome is lifted mechanically, and as the gas is spent, the dome returns to its original form (means touches the digester). Always monitor the liquid in the water jacket for appropriate floater operation (oil/water can be used in the jacket). Check the instructions for the floater size. The floater is connected to the flexible pipe at the output to suck the bio gas and deliver it to the filter at a pressure of 5 bar with the aid of a little booster pump.

3.3. Filter Unit

The filters are used to remove CO2, H2O, and H2O from raw biogas, reducing it to 90 to 94% methane (separation of other gases and retaining the CH4). PSA is the filtering technology employed (Pressure Swing Adsorption). Three separate cylindrical jars with adsorption material packed within them were employed to perform surface adsorption and then released from their surfaces after the time period specified.

Figure 4 Filters

3.4. Engine Specifications

Biogas was created in a digester at the Government Engineering College-Rewa laboratory. The biogas and gasoline were combined in a 20:80 ratio using a nozzle and an airtight glass bottle. The chromatographic test was performed on the utilised biogas. A 5hp single cylinder four stroke Spark ignition engine AC dynamometer was used for the performance test. Tables 1 and 2 provide the technical characteristics of the engine test rig and dynamometer, respectively. The engine performance statistics were evaluated between 1000rpm-3500rpm, with 500rpm increments.

The engine was initially powered by gasoline and afterwards by a biogas-petrol mixture. The dynamometer control unit read the torque, exhaust temperature, and fuel consumption immediately, while the brake power, indicated power, specific fuel consumption, indicated thermal efficiency, brake thermal efficiency, and mechanical efficiency were computed.

Table 1 Technical characteristics of the engine test rig

S. No.	Parameter	Specification
1	Type	Four stroke, single cylinder, spark ignition engine
2	Bore	70mm
3	Stroke	60mm
4	Maximum Power	5hp @ 4000rpm
5	Displacement	144cm3
6	Compression Ratio	21:1
7	Swept Volume	230cm3

Figure 5 Engine Test Rig

Table 2 Technical characteristics of the Dynamometer

S. No.	Parameter	Specification
1	Maximum operating Capacity DC	12V, 8.3A
2	Maximum Speed	4000rpm
3	Maximum operating capacity AC	Single phase, 220V, 50Hz
4	Torque arm radius	25mm

1. Loading Configuration (Rope Brake Dynamometer)

A Rope Brake Dynamometer setup with a brake drum attached to the engine shaft and a cooling water system as well as spring balances. The weight may be adjusted by turning the hand wheel on the frame and altering the rope tension on the braking drum.

2. Fuel Input Measuring System

It comprises of a gasoline tank that is appropriately positioned on a stand. The stand is attached to the air tank, and fuel flows from the reservoir to the fuel filter via a burette. The burette makes it possible to measure fuel usage over a set period of time using a stopwatch.

3. Loading Configuration (Rope Brake Dynamometer).

4. Fuel Input Measuring System

It is done with the assistance of the supplied bio gas flow metre (if utilising the gas directly) or with the CBG cylinder by weight of the cylinder.

5. Arrangement for Measuring Air Intake

It is made up of an air tank with an aperture plate and a differential manometer that measures the rate of flow of air sucked by the engine.

6. Measurement of the Heat Carried Away by Exhaust Gases

It is made up of an exhaust gas calorimeter, which measures the heat transported away by exhaust gases. A centre tube and an outer jacket make up an exhaust gas calorimeter. Exhaust gases travel via the centre tube, while water circulates in the outer jacket to achieve the greatest temperature differential between the entrance and output of the calorimeter. The volume of water circulated is measured using a measuring cylinder and a timer. Thermocouples are given to measure the temperature of the exhaust gases and water circulated.

4. RESULTS AND DISCUSSIONS

Torque, specific fuel consumption, braking power, brake thermal efficiency, brake mean effective pressure, mechanical efficiency, indicated thermal efficiency, and exhaust temperature at various speeds were compared with those ran on gasoline in this chapter.

4.1. Torque

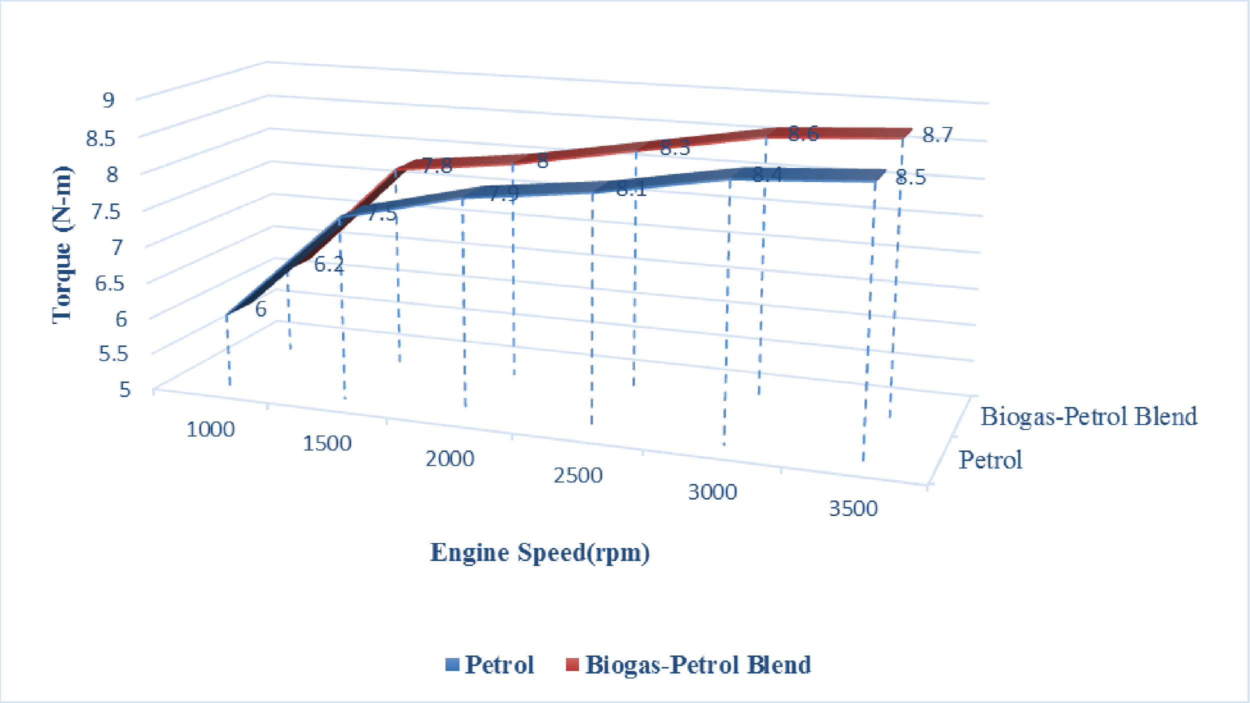

Figure 6 The Graph of Torque (Nm) against Engine Speed

The torque the engine produced increased as the speed did for the two fuels. The obtained torque varied between 6.2Nm and 8.7Nm for the biogas-petrol blend fuel and between 6Nm and 8.5Nm for the gasoline fuel. This is because the biogas-petrol mixture produced more energy when burned compared to pure gasoline because of its marginally higher heating value. At a speed of 3500 rpm, the highest torque readings of 8.5Nm and 8.7Nm for gasoline and a biogas-petrol blend, respectively, were recorded. Additionally, as the speed rises, the amount of torque produced rises as well, though with less fuel used per unit of time. According to the design of the curves in Fig. 6, increasing speed will result in more torque.

4.2. Fuel Mass Flow Rate

The two fuels' combined fuel mass flow rates rise as engine speed rises. Until the fuel mass flow rate for the biogas-petrol blend increased more than that of gasoline, as shown in Fig. 7, there were no appreciable differences in the parameters for the two fuels. This may be because biogas petrol blend flows more easily than gasoline because it has a slightly lower density (739.2 kg/m^3) than gasoline (740.5 kg/m^3).

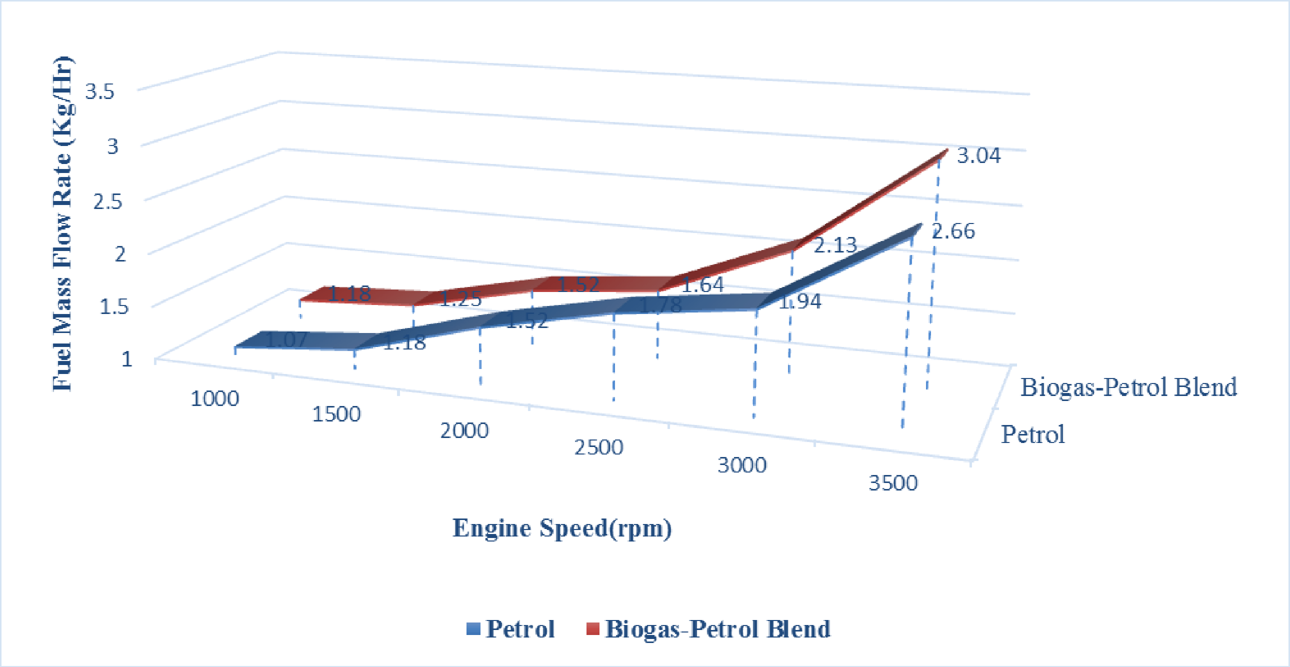

Figure 7 The Graph of Fuel mass flow rate against Engine Speed

4.3. Brake Power

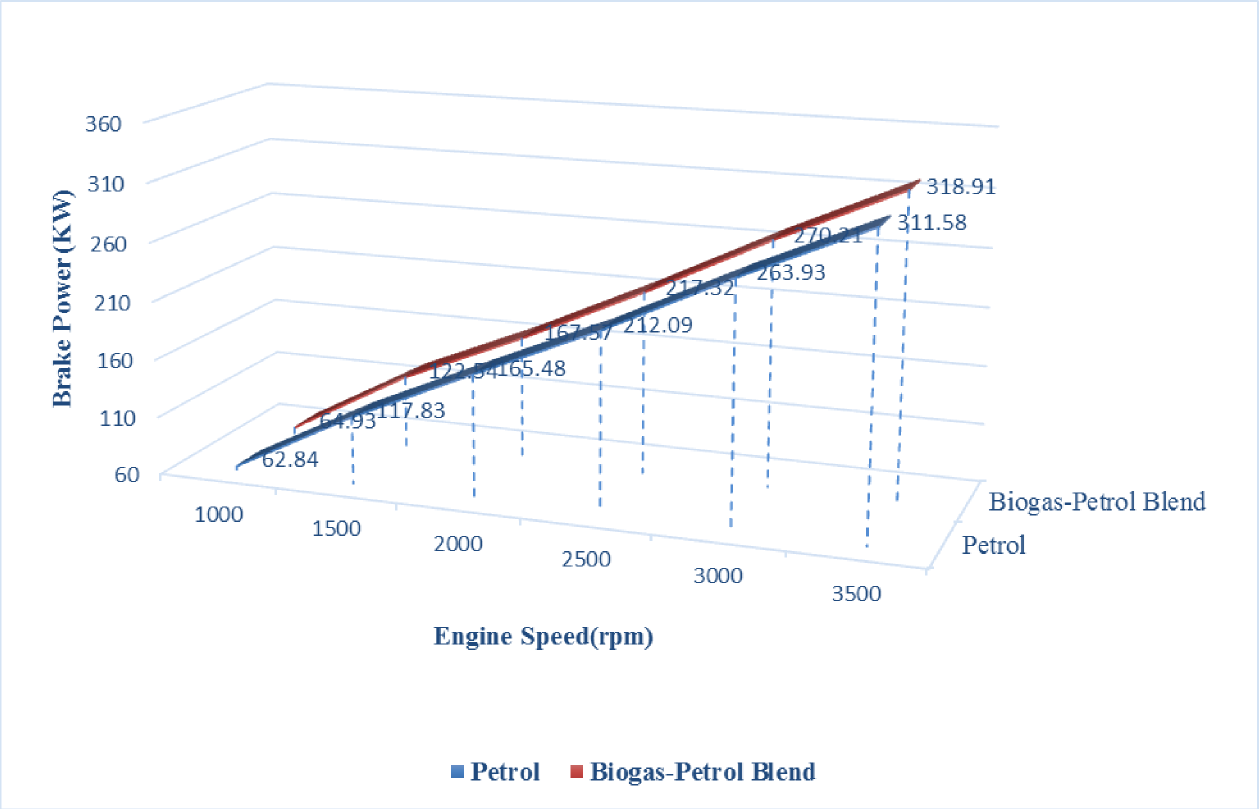

Figure 8 The Graph of Brake Power against Engine Speed

Figure 8 illustrates how the engine performs in terms of brake power when running on gasoline and a biogas-petrol blend. When compared to pure petrol, the brake power of the biogas-petrol blend was marginally higher. This is explained by the fact that the biogas-petrol mixture produced more energy after combustion at a given speed because it has a slightly higher heating value than gasoline. According to Fig. 8, engine speed increases with an increase in brake power. For the biogas-petrol blend and gasoline, respectively, the highest brake power measurements were made at maximum speed of 3500rpm and were 311.58kW and 318.91kW, respectively.

4.4. Specific Fuel Consumption

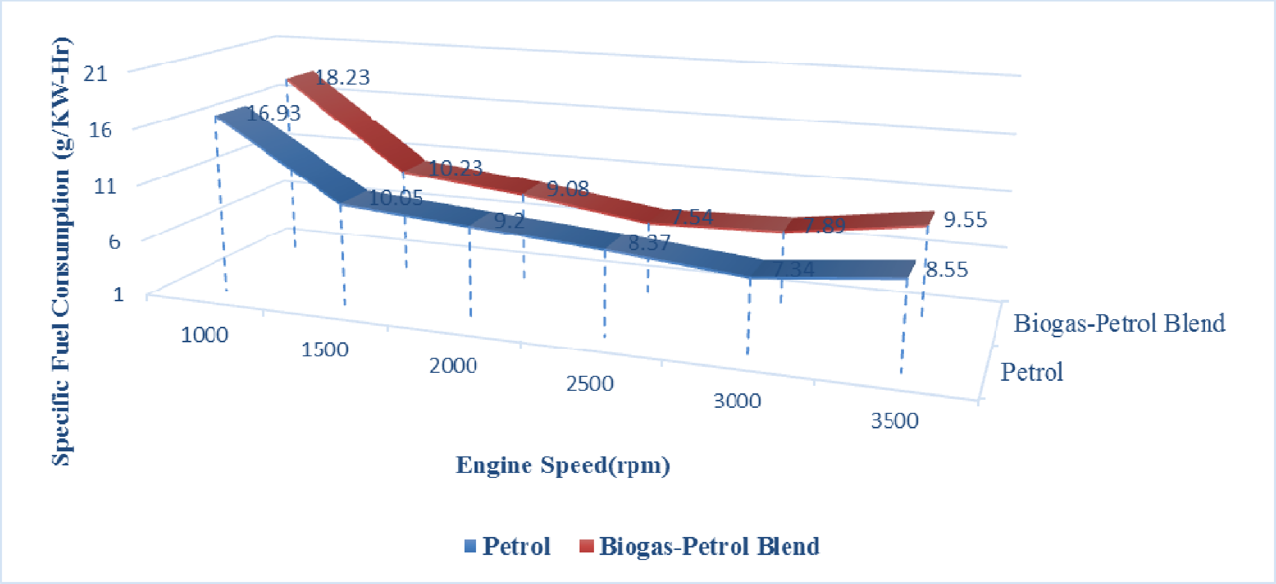

Figure 9 The Graph of Specific Fuel Consumption against Engine Speed

In Fig. 9, the engine performance in relation to specific fuel consumption is displayed. As the engine speed rose, the Specific Fuel Consumption fell.

In the same way that the fuel mass flow rate speed is higher than that of petrol fuel at those speeds, the specific fuel consumption for the biogas-petrol blend was higher than that of petrol at an engine speed greater than 2750 rpm. The need for more power at speeds above 2750 rpm led to an increase in flow rate and fuel consumption, which can be used to explain this. The significantly higher specific fuel consumption of the biogas petrol blend can also be attributed to the higher specific gravity and viscosity of the gasoline, which increased the amount of fuel used to produce one unit of energy. Additionally, increased fuel viscosity could lead to increased gas emissions and fuel consumption because it lowers the quality of fuel atomization.

4.5. Brake Thermal Efficiency

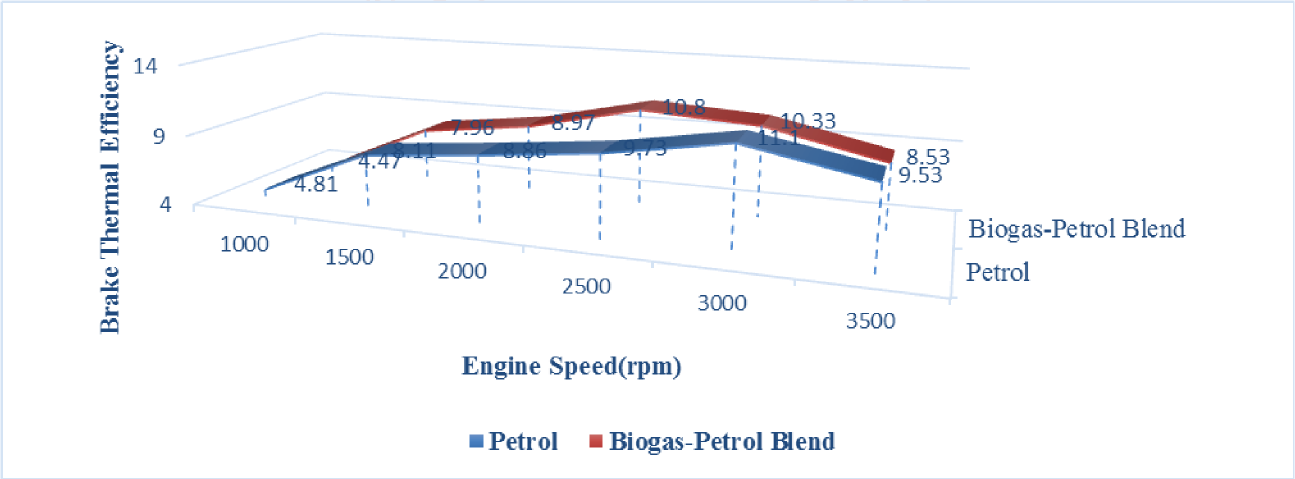

Figure 10 The Graph of Brake Thermal Efficiency against Engine Speed

The performance of the fuels on an ICE test bed in terms of brake thermal efficiency is shown in Fig. 10. Petrol demonstrated a higher thermal efficiency for braking than biogas petrol fuel, especially above 2750 rpm. The second law of thermodynamics states that a reduction in heat loss from an engine through heat transfer to the coolant and to atmosphere results in an increase in engine thermal efficiency. The efficiency is also inversely correlated with the amount of fuel used specifically for braking. A biogas-petrol blend has a lower ignition temperature than gasoline, which may speed up engine combustion and increase thermal efficiency. According to [Plint and Patners 1987], the decline in brake thermal efficiency, especially at higher speeds, shows an inverse relationship between fuel consumption and thermal efficiency. This highlighted the necessity of operating engines close to their maximum power output or speed to ensure a good return on the fuel burned. Increased engine mechanical losses in relation to useful power output, throttling losses, and a decline in combustion efficiency were the causes of the decrease in thermal efficiency. On the test bed, it was discovered that the two fuels generally exhibited the same behaviour.

4.6. Brake Mean Effective Pressure

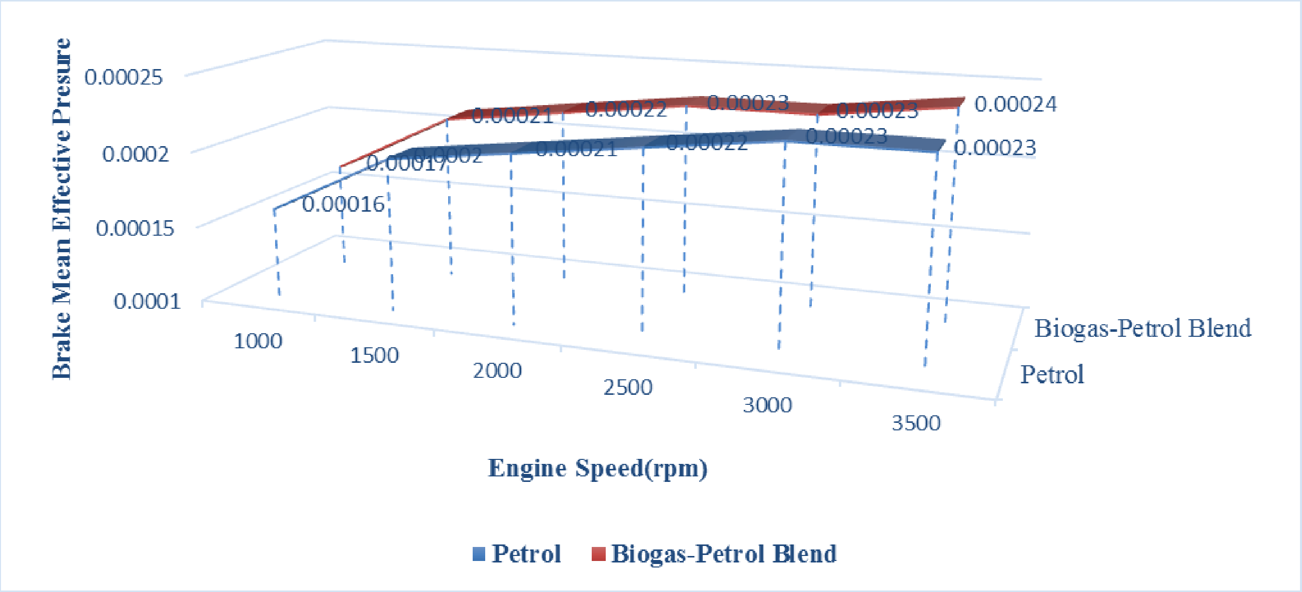

Figure 11 The Graph of Brake mean effective pressure against Engine Speed

Fig. 11 shows the engine performance in relation to the brake mean effective pressure. The calculated mean pressure that would have an effect on observed power output in the absence of mechanical losses is known as the brake mean effective pressure. This parameter behaved similarly to brake power and torque. The biogas-petrol blend had higher values at all speeds than gasoline, and the brake mean effective pressure increased as the speed increased.

4.7. Mechanical Efficiency

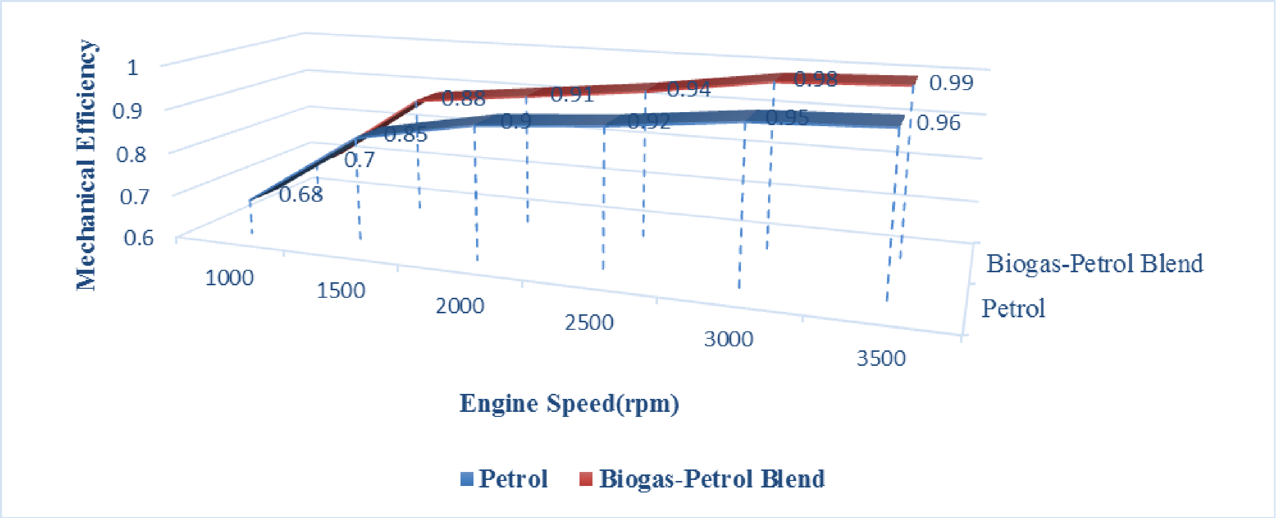

Figure 12 The Graph of Mechanical Efficiency against Engine Speed

When used on a test bed, the biogas-petrol mixture produced greater mechanical efficiency than gasoline at a specific speed. This is explained by the fact that biogas-petrol blends produce more power than pure gasoline. According to Fig. 12, mechanical efficiency rises gradually after a sharp increase between 1000 and 1500 rpm.

5. CONCLUSIONS

There are particular difficulties associated with using biogas as an internal combustion fuel, including the requirement to modify some engine specifications and some engine components. It is currently not possible to use biogas to power an IC engine. Running a spark ignition engine only on biogas is more of a challenge than blending biogas and gasoline. Thus, a biogas-petrol mixture might be considered a real and useful replacement for independent spark ignition engines. While consuming less fuel and heating the exhaust, an engine with a spark ignition and biogas-petrol fuel in the ratio 20:80 generates better torque, brake power, indicated power, brake thermal efficiency, and brake mean effective pressure. Fueled by a spark ignition engine, a biogas-petrol mixture is more affordable, ecologically beneficial, and aids in the production of fertiliser and trash disposal.

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