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Research Article

Improved portable generator performance with bio-ethanol fuel and its impact on bio-sustainability

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ABSTRACT

Clean air, renewable energy, climate change, safe environments, and the opportunity to live in a healthy community are just a few of the many issues that fall under the umbrella of environmental sustainability. The creation of bioenergy and biomaterials has the potential to retain the energy-environment relationship while simultaneously fostering cleaner, lower-carbon settings. Scientists are investigating renewable energy sources like ethanol to enhance sustainability and the planet›s health. Fuel ethanol is a feasible alternative to gasoline since it has a lower carbon footprint and a higher energy density. This research summarizes ethanol›s potential as a bio-sustainable fuel option for portable generators in India. Bio-ethanol testing was done on a portable generator with an ethanol-gasoline blend, and the findings are presented in this study. Compared to using standard gasoline, the results show 9% to 25% increased thermal efficiency and 6% to 28% decreased fuel usage. The results showed a decrease of 6%–23% in carbon monoxide and 3%–11% in unburned hydrocarbon emissions.

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INTRODUCTION

In current flex-fuel engines, a fuel composition sensor may automatically adjust fuel injection and spark timing to maximise combustion of any percentage of the resulting blend. Ethanol is the most widely available commercial biofuel, and there have been about 60 million ethanol-capable vehicles, motorcycles, and light-duty trucks sold around the world. The internal combustion engine of a flexible-fuel car, also known as a dual-fuel vehicle, can run on either ordinary gasoline or an alcohol or ethanol-based fuel. The gasoline or a gasoline/ethanol blend up to eighty five percentage content can be used to power a vehicle with a flexible fuel engine [1, 2].

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"Bio-sustainability" describes a regenerative and restorative economic approach. Differentiating between technical and biological cycles, its major goal is to ensure that all products, components, and materials always have the highest possible level of utility and value. Focusing on making the most of scarce resources, bio-sustainability seeks to maximise the reuse and recycling of those items for as long as it's financially possible to do so. Bio-refining is one of the most crucial essential enabling technologies of bio-sustainability, as it helps to complete cycles of raw biomass materials, minerals, water, and carbon. Hence, bio-refining is the best method for the large-scale, ecologically sound utilisation of biomass in the bio-economy. Optimal social, economic, and environmental outcomes will arise from the cost-competitive co-production of food and feed components, bio-based products, and bioenergy [3–5].

Bioenergy is gaining popularity as a renewable energy source that can help manage increasing energy costs. It also has the potential to generate revenue for disadvantaged farmers and rural populations globally. Bioethanol derived from agricultural residual-biomass offers significant environmental, socioeconomic, and strategic advantages and is a viable, cleaner substitute for conventional fossil fuels [6, 7]. The study looked into how a bio-ethanol engine burnt the ethanol. Improved performance and thermal efficiency were the goals of an inquiry into the use of high-compression hydrous ethanol reforming and supercharging in lean-burn circumstances. When ethanol was mixed with gasoline, nitrogen oxide emissions went up [8]. Hydrocarbon and carbon monoxide emissions are reduced to their minimum levels. It was shown that varying the ethanol-to-gasoline ratio in fuel mixes led to noticeably varied energy efficiency and pollutant levels under a wide variety of loading circumstances. Emissions levels were found to be higher when the engine was under more strain, but lower when the percentage of ethanol was raised [9].

The research looked at the effects of combining ethanol and gasoline on power, torque, fuel consumption, and emissions using analytically studied steady-state engines. Research on the usefulness of gasoline-ethanol blends in engines has primarily concentrated on ethanol mix rates up to 20% [10]. Several studies showed minimal to no reactivity at 10% volume ethanol, indicating that engine operating conditions have a greater influence on the characteristics of the engine and the contaminants it produces at low ethanol blend levels. More focus recently has been placed on the efficiency of spark-ignition (SI) engines using ethanol-gasoline blends while keeping the fuel-air ratio constant [1].

The volumetric efficiency typically decreases with increasing engine speed and decreasing ethanol concentration in the fuel mixture. This is a measurable phenomenon. When the percentage of ethanol in the fuel mix exceeds that of gasoline, the amount of harmful emissions is significantly cut down [11]. More saturated hydrocarbon emissions were produced when the percentage of ethanol in the fuel mix was raised above 25%. Higher ethanol concentrations in the fuel mixture led to the release of more aromatic chemicals and unburned ethanol than lower ethanol concentrations did. When the vehicle picked up speed, it also reduced its emissions across the board. This is because there are more oxygen atoms in an ethanol molecule than in those of other types of alcohol, which is why it has a higher boiling point. The fuel will require more air to burn, so make preparations accordingly [12].

There is a strong correlation between the widespread adoption of fuels with 10–15% ethanol and the possibility to drastically reduce emissions. Increased ethanol content in fuels reduced emissions significantly compared to conventional fuels. Through the use of a dual fuel system, emissions of carbon monoxide, hydrocarbons, and smoke were all noticeably cut down. The amount of carbon dioxide and nitrogen oxides released into the environment, however, rose with both the oxidation of the combustion process and the temperatures at which the combustion occurred [13, 14].

The amount of water used in the production process has a direct effect on the amount of energy needed to produce ethanol. Hydrous ethanol increased the flame's growth and decreased the time it took to spread, but had no influence on the flame's stability. The mixture of gasoline, methanol, and ethanol was tested for its consistency and homogeneity after being combined [15]. Methanol increases power output over gasoline in any mixture, regardless of operating conditions. Adaptations to the combustion system have been made to allow for the use of novel fuels such methanol/gasoline, ethanol/gasoline, and their respective combinations. As a result of these and other variables, it is difficult to establish generalisations about the effect of ethanol or methanol on emissions. As a result of the interconnected nature of these elements, drawing conclusions is difficult. In tests, using fuel blends with less than 20% ethanol had no discernible effect on either engine performance or torque. As the percentage of blending was increased, however, the engine's performance dropped [16–18]. In order to achieve bio-sustainable aims, this study provides an overview of ethanol as a potential alternative fuel for flex-powered portable generators. In this study, we provide the findings of Bio-ethanol tests performed on a light-duty portable generator operating on an ethanol-gasoline with incremental blend.

MATERIAL AND METHODS

Ethanol has a higher octane rating than gasoline, which means that it can help to increase the performance of high-compression engines. In fact, many high-performance engines are designed to run on fuels that contain ethanol. However, lower-compression engines may not see the same benefits and could even experience a decrease in performance. Ethanol is a renewable fuel that can be produced domestically and has a higher octane rating than gasoline, thus it may be used in place of gasoline without compromising on performance. Several rural areas have high unemployment rates and can benefit greatly from

Table 1. Properties of Bio-ethanol

Sl.No	Property	Unit	Ethanol	Gasoline	ASTM Testing
1	Lower Heating Value	(MJ/kg)	26.9	44.0	ASTM D240
2	Kinematic Viscosity, at 20 °C	(cSt)	1.5	0.5	ASTM D445
3	Density, at 15 °C	(kg/m^3)	785	737	ASTM D4052
4	Flash Point	(°C)	14	-40	ASTM D93
5	Research Octane Number	RON	115	90	ASTM D2699
6	Motor Octane Number	MON	100	82	ASTM D2700
7	Oxygen (%)	-	35	0	ASTM E385
8	Stoichiometric air/fuel ratio	-	8.9	14.5	ASTM D5291

the manufacturing of ethanol. To some extent, ethanol, a bio-organic fuel, could replace fossil fuels in cars. It could greatly help in decarbonizing transportation and enhancing environmental performance [13]. The effects of blending ethanol with gasoline on fuel quality are examined. In this case study, we use empirical evidence to show that blending ethanol with gasoline dramatically boosts both knock resistance and full-throttle performance. Basic effects of ethanol combustion are examined, as well as the reduced enrichment need under high speed/high load circumstances, which could lead to smaller, slower designs [1].

Ethanol can be used as a standalone fuel or combined with gasoline for spark-ignition engines. The BIS Standard 2796: 2013 in India allowed for an ethanol blend of 10% in gasoline in 2013, and this percentage may increase in the future. It would be very helpful to understand how ethanol-blended fuel performs in a modern gasoline engine. The Indian government formerly required 10% ethanol in gasoline as part of an effort to lessen the country›s reliance on foreign oil [13].

Portable generators are still often utilised for power generators in India, despite their high pollution rates. However, several adjustments will be needed to increase the engines' combustion rate and thermal efficiency. Since renewable energy sources are not always available throughout India or during all seasons. Ethanol is an alternative fuel produced primarily from corn and sugarcane. To reduce the reliance on fossil fuels and carbon footprint, ethanol is an attractive alternative to gasoline. With the inclusion of OH components, gasoline not only improved full combustion but also had less harmful emissions. The gasoline engine's flaw was that it could only run for brief periods of time due to the decrease of harmful emissions, which had an influence on the combustion potentiality or capacity to burn for a shorter time [19]. The properties of gasoline and ethanol was tabulated in Table 1 [19].

EXPERIMENTAL DATA

A low-duty power generating engine that uses flexible fuel was tested. A spark ignition engine with a compression ratio of 5:1 and a peak output of 4hp at 3300 rpm was chosen for this experiment. Single-cylinder, four-stroke air-cooled engine with 175 cc work capacity as tabulated in Table 2. Both with and without an bio-ethanol blend, the essential test runs were performed under four load conditions, spanning from 25% to 100% capacity, to ensure the optimum performance and lowest emissions. A light duty power producing engine is shown in Figure 1 [14]. It was essential to initially start the engine with gasoline, and after that, it was put through a series of tests that continued until the conditions of its steady-state operation were determined. The hydrocarbon, carbon monoxide, and oxygen emissions, in addition to the brake thermal efficiency and specific fuel consumption, were all put to the test. Each and every one of the test runs was carried out with weights that were in direct proportion to the total load weight.

Table 2. Experimental engine specification

Parameter	Description
Engine type	Four-stroke, single-cylinder
Cooling system	Air-cooled engine
Compression ratio	5:1
Rate Power	4 hp @ 3300 rpm
Displacement	175 cc

Emission measurements were analysed using the Crypton CGP-680 Analyzer (Table 3)[20]. This exhaust gas analyzer is totally microprocessor-controlled and uses Non-Dispersive InfraRed techniques. The device is capable of measuring carbon monoxide, carbon dioxide, and hydrocarbons. Electrochemical oxygen measurement and a chemical sensor for detecting nitrogen oxide are utilised in a second channel provided. When working at pressures between 750 and 1100 bar, the reaction time to 95% of the final measurement is just ten seconds. To function properly, a minimum flow rate of five lpm must be maintained.

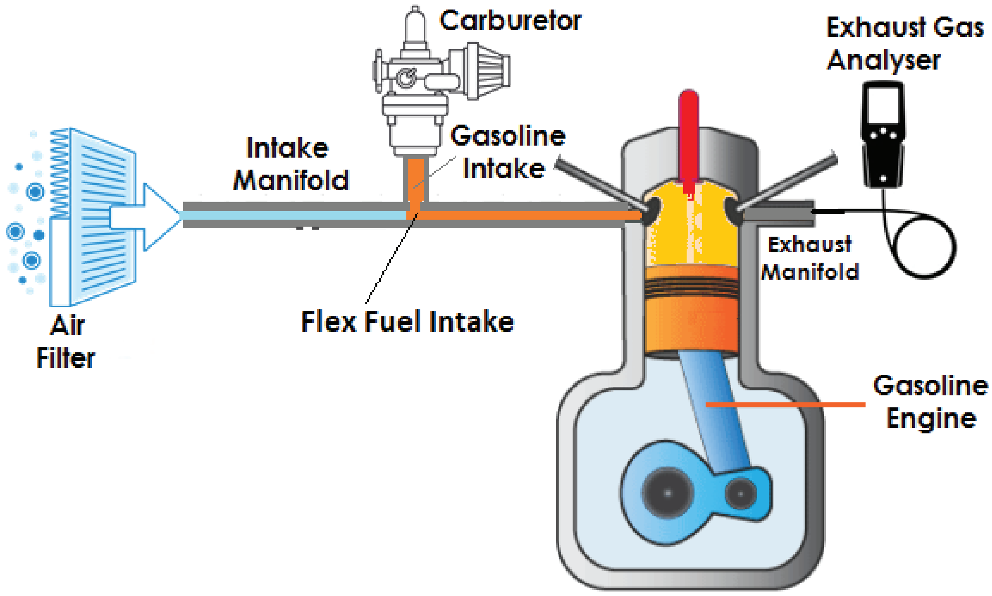

Figure 1. Schematic diagram of the Bio-ethanol Setup [14].

Table 3. Instrumental parameters of Emission analyser

Measurement	Range	Accuracy	Resolution	Instrument
CO	0 to 10%	± 0.03%	0.01% vol.	Crypton 680 series Analyser NDIR technique
HC	0 to 10000 ppm	± 10 ppm	1 ppm vol.	Crypton 680 series Analyser NDIR technique

The exhaust system was hooked up to a Crypton CGP-680 Analyzer so that emission levels could be determined for different fuel combinations and operating loads. By comparing the findings to those obtained from base fuel measurements, the percentage of deviation for each parameter can be determined [20].

The exhaust system was connected to an emission analyser from the Crypton 680 series during the experiment so that emission levels could be determined for different fuel mixtures under different loads. To calculate the percentage of variation for each parameter, one needs to compare the measured value with the value for the base fuel. The engine was started with gasoline and put through a battery of tests to ensure it was operating at a constant rate. Emissions of carbon monoxide, hydrocarbons, and fuel consumptions were analysed, along with thermal efficiency. In order to simulate the actual load, the test runs were performed using weights of varying sizes. The same procedures are used when enriching gasoline with a blend of bio-ethanol. In this study, an air-cooled, spark-ignition, single-cylinder, four-stroke engine with an incremental load was used to explore the effects of Bio-ethanol on engine performance and emissions. Tests were conducted using bio-ethanol at 10%, 15%, 20%, and 100% concentrations. In this paper, BE refer to bioethanol and BE10 referred to 10% of bioethanol and 90% of gasoline. BE15 referred to 15% of bioethanol and 85% of gasoline and similarly, BE20 referred to 20% of bioethanol and 80% of gasoline. BE100 is 100% bioethanol.

RESULT AND DISCUSSION

Study on Brake Thermal efficiency

When ethanol was added to the mixture, combustion efficiency increased (as seen in Figure 2). Maximum ethanol thermal efficiency increases to 9.4%, 16.2%, and 25.2%, showcasing a substantial performance enhancement at full load. When combined with oxygen, ethanol accelerates combustion and increases energy efficiency. Because of its improved efficiency and other distinguishing features, this cycle becomes closer to its intended state of constant volume combustion. The Bio-ethanol engine benefits from this development since higher hydrogen flame velocities and a more diverse set of flames result in greater efficiency. The combustion process is slowed down during testing with varied loads when ethanol is not present. However,

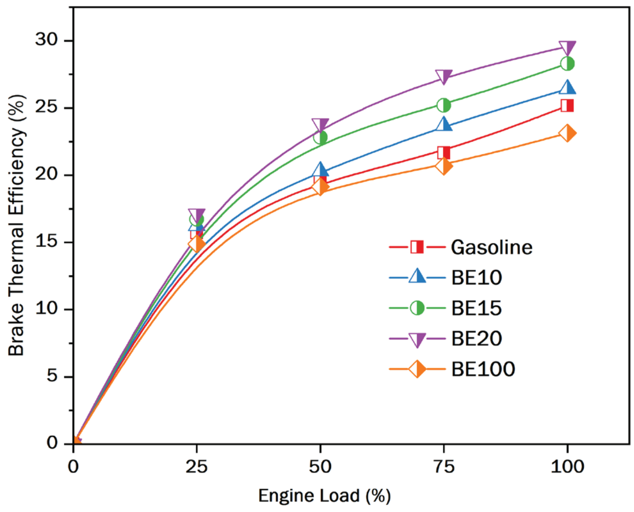

Figure 2. Study of Bio-ethanol on brake thermal efficiency.

ethanol dramatically sped up the combustion process, which improved the efficiency of the heat produced. Ethanol and gasoline have a lower stoichiometric ratio. It's possible that the same amount of air can be used to burn the larger quantity of fuel. Because the lean mixture entirely occupies the remaining space, more fuel is used [17].

Study on Specific fuel consumption

Figure 3 depicts the ethanol and conventional gasoline brake fuel consumption under four different loads. It was demonstrated that gasoline consumption will grow regardless of the mix condition, even if the starting engine load was reduced. It's also important to note that ethanol's smaller heating valve compared to gasoline means that temperature fluctuations will be load-dependent.

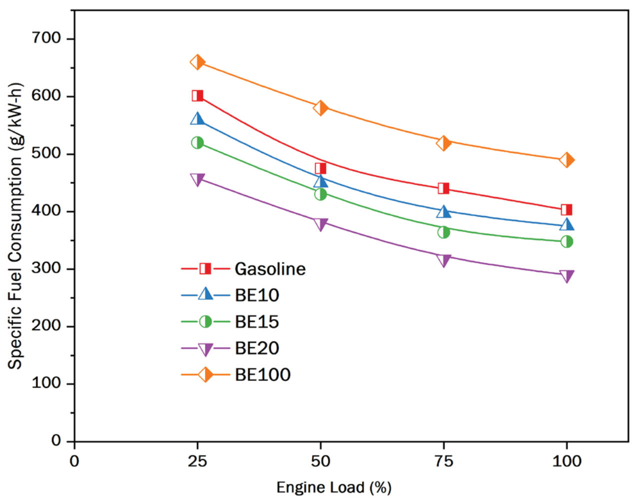

Figure 3. Study of Bio-ethanol on specific fuel consumption.

The specific fuel consumption of the engine is reduced by 6% to 28% depending on the blend when ethanol is included. Results showed that when compared to utilising gasoline, fuel consumption was reduced by 28% when using 20% ethanol. With the addition of hydrogen and oxygen, gasoline was able to burn more efficiently, producing a bigger flame thrust and higher calorific values than was previously possible with gasoline alone [12].

Study on Carbon Monoxide Emission

The rate of CO emissions versus engine load is shown in Figure 4. The amount of carbon monoxide (CO) released depends on several elements, the most important of which are the efficiency of the combustion and the air-to-fuel ratio. The engine was maintained at its most fuel-efficient cruising speed in order to minimise CO2 emissions. The combustion process was enhanced and CO emissions were decreased by using ethanol in tandem with oxygen. Emissions reductions may have resulted from the use of oxygenated chemicals, which improve CO combustion in the cylinder or in post-combustion activities. The diluting the gas may not be the only option for reducing CO emissions. There is a 6%-23% range for CO reduction when using ethanol blends that promote better combustion and enhance the efficiency of lean-running engines. Chemically speaking, ethanol is preferable because it burns more quickly and has a broader range of combustibility. When a mixture of ethanol and gasoline is ignited, it burns quickly and fully, destroying the pure gasoline altogether [8, 21].

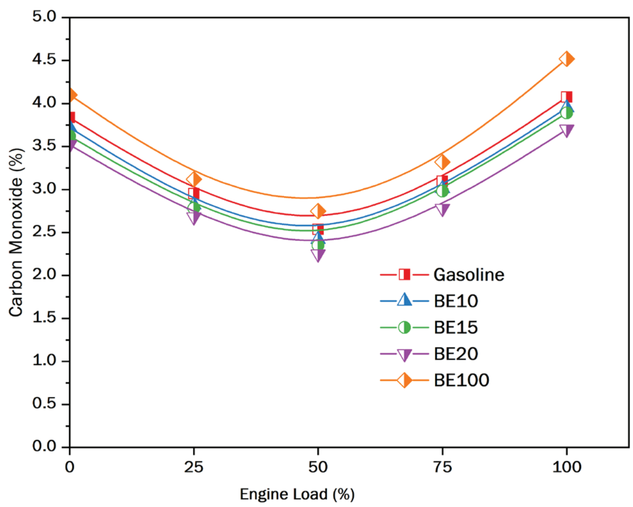

Figure 4. Study of Bio-ethanol on carbon monoxide.

Study on Unburned Hydrocarbon Emission

Adding ethanol reduced the amount of unburned hydrocarbons released into the exhaust for all loads, as seen in Figure 5. Results showed that when ethanol and HC were used together, the HC concentration was significantly reduced in all loads tested. Better engine performance and more complete combustion were both results of using ethanol. As a result of variations in ethanol flow rates, the percentage decreases in unburned hydrocarbon volume varied from 3% to 11%. Hydrogen's quicker quenching time than gasoline's lowers hydrocarbon emissions. Due to the poor flammability of ethanol and the comparatively high in-cylinder pressure and temperature produced by the rapid flame velocity, fuel mixes containing ethanol reduced hydrocarbon emissions. Because of the increased oxygen provided by the ethanol mixture, combustion is more complete and produces less HCs [22].

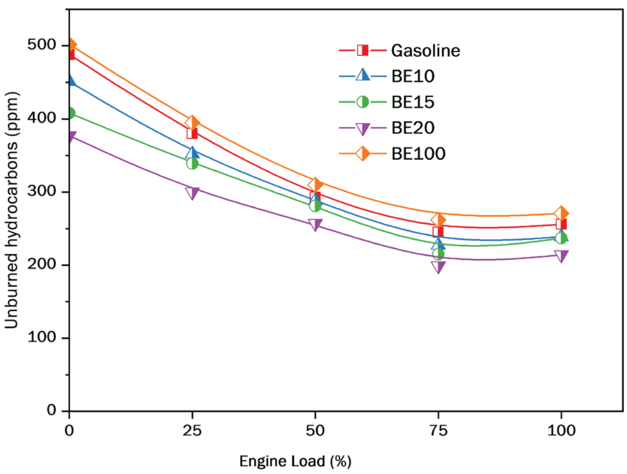

Figure 5. Study of Bio-ethanol on unburned hydrocarbon.

Influential study of Bio-ethanol on portable generator performance

Contour plots are made through Minitab software with full factorial design, which comes under the design of experiments. In this paper, bioethanol ratio and engine load were selected as the parameters, and fuel consumption, efficiency, and emission formation were studied as the response parameters. A contour plot can show the relationship between a fitted response and two continuous variables when a model is stored. A contour plot shows data in two dimensions. Connecting spots with the same response value forms contour lines.

According to the contour plots in figure 6 and 7, the amount of fuel consumption, the greater load condition, and the percentage of bio-ethanol utilised in the fuel had the greatest impact on the total amount of energy that was consumed by the engine. In addition, the amount of gasoline that is consumed is significantly affected by the amount of bio-ethanol that is present in the fuel mixture. The lowest values are attained when the engine is working at maximum load circumstances with a concentration of 20% bio-ethanol. It is hypothesised that the origin of this occurrence is an increase in the quantity of oxygen that is present in the air, which causes a quicker rate of burning [16]. Ethanol burns faster with oxygen. This cycle approaches constant volume combustion due to its increased efficiency and other properties. This improves bio-ethanol engine efficiency by increasing hydrogen flame velocities and flame diversity. Without ethanol, variable load testing slows combustion. Ethanol accelerated combustion, increasing heat efficiency. Ethanol and gasoline have lower stoichiometry. The same air might burn more fuel. The lean mixture fills the leftover area, using more fuel [23].

As a direct result of this contour plots Figure 8 and 9, the amount of fuel that can be burnt effectively was lowered. It is possible that the quantity of carbon monoxide and hydrocarbons that are emitted into the environment can be decreased by using biofuel blends that include at least 20% bio-ethanol. In addition, ethanol has a lower carbon-to-hydrogen ratio than gasoline, which means that it has a higher

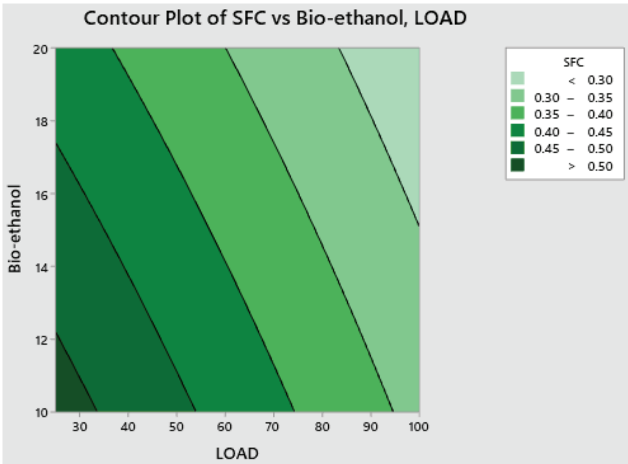

Figure 6. Influential study on Fuel Consumption.

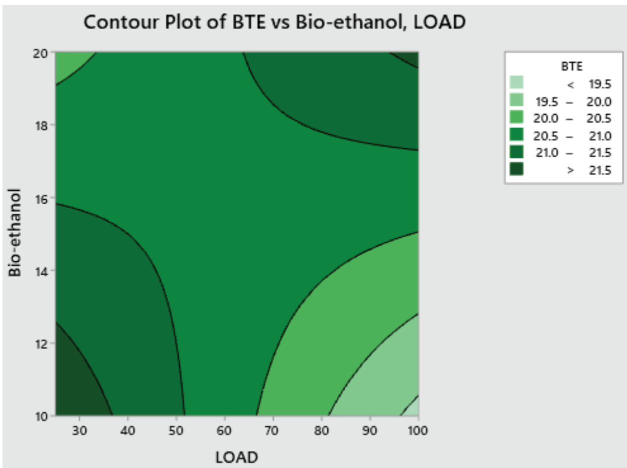

Figure 7. Influential study on Brake thermal efficiency.

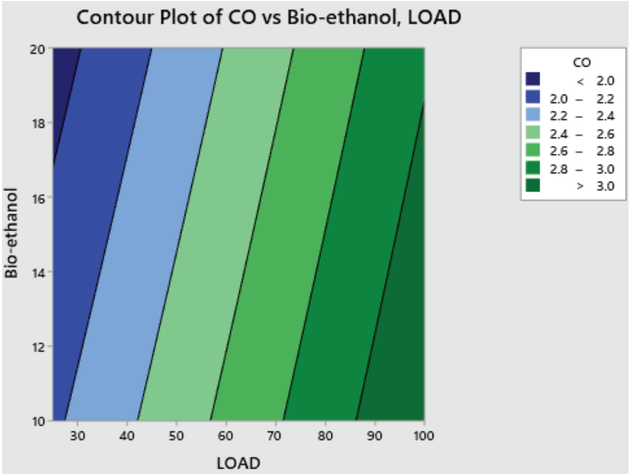

Figure 8. Influential study on Carbon Monoxide emissions.

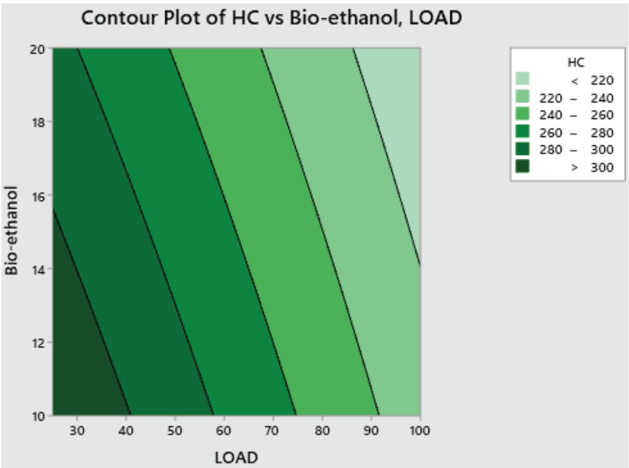

Figure 9. Influential study on Hydrocarbon emissions.

oxygen content. This can lead to more complete combustion and lower emissions of pollutants like carbon monoxide and hydrocarbons. There is a proportional reduction in the amount of carbon monoxide and hydrocarbons released whenever there is a larger proportion of bio-ethanol present. When applied at a concentration of 20%, bio-ethanol produces the fewest amounts of carbon monoxide and hydrocarbon emissions possible. This can be explained in part by the rapid acceleration of the combustion process that takes place at such a height, which is a significant contributor to the phenomenon [10, 16].

IMPLICATIONS FOR ENVIRONMENTAL AND BIO-SUSTAINABILITY

Biodiversity is a crucial component in promoting sustainable development and enhancing the economic prosperity of societies by providing a continuous supply of natural resources and ecological services. Integration of recycling and bioconversion for enhanced process performance is also assessed. The goal of this work is to make it easier to recycle bio-waste for applications in bio-sustainability. In order to commercialise and promote the use of alternative commodities, more research, market analysis, and funding are required. Use a comprehensive, methodical approach that incorporates several fields and makes extensive use of data to enhance existing practises and develop innovative new ones in order to get the most out of bio-waste [24]. Issues on a global scale can be helped by bio-sustainable practises. By using biomass as an alternative to petroleum, the environmental effect of producing bioenergy and biomaterials could be reduced. Carbon management and GHG emission reductions could benefit from the bio-refinery associated with sustainable waste management. By cutting down on emissions of greenhouse gases, a low-carbon economy is exemplified by a waste bio-sustainable refinery's approach to processing its raw materials [25].

In comparison to fossil fuels, bio-ethanol may be safer due to its ability to be diluted in water, broken down by bacteria, and dissipated quickly. Since ethanol can be produced in nearly any country, it is the most economical energy option. Ethanol can be made from a variety of plants, including corn. Many types of ethanol exist, but the most common variety is simply called "E10," and the percentage of E10 in blends varies from country to country, typically falling within the range of 10 to 15%. The United States and Brazil are only two of the many places where a high-ethanol gasoline blend (anything from 50% to 85% ethanol) is legal [9, 26]. The simplicity of producing ethanol results in lower production costs than those of fossil fuels. Only carbon dioxide and water are released as by-products when ethanol is burned as fuel. Carbon dioxide emissions are a little contributor to the pollution problem. "Atmospheric carbon neutrality" is thought to result from the combustion of ethanol made from biomass sources like corn and sugarcane. This is because carbon dioxide is taken in by the biomass during its growth, and this may offset the quantity of carbon dioxide released during ethanol combustion. The three main foci of bio-sustainability are the feedstock, the production process, and the distribution of the final product. The firm never gave the afterlife of the product the respect it deserved. How the product will be maintained after its useful life has ended is not something that has been thought through [3, 24, 25].

Bio-ethanol produces significantly fewer greenhouse gas emissions than gasoline or diesel. When bio-ethanol is burned, it releases carbon dioxide, but this is offset by the carbon dioxide absorbed by the crops used to produce it. In contrast, gasoline and diesel are produced from fossil fuels, which release carbon dioxide that has been trapped underground for millions of years and contribute to the accumulation of greenhouse gases in the atmosphere. The production of bio-ethanol can promote sustainable agriculture practices. It can encourage farmers to grow crops specifically for energy production, which can help to diversify their income streams and reduce their reliance on traditional crops [2].

Emissions reduction from a portable gasoline generator is the primary focus of this investigation. Damage to the blood's ability to carry oxygen to and from tissues makes carbon monoxide a serious health risk. When blood comes in contact with carbon monoxide, haemoglobin is quickly converted to carboxy-hemoglobin. Because of the presence of carbon monoxide in the lungs, haemoglobin is not able to reach a fully oxygenated state. It has also been shown that exposure to this hydrocarbon lowers the production of white blood cells, suppresses the immune system, and makes the body more vulnerable to infection. There's also the fact that different stages of a plant's life cycle are susceptible to different levels of pollutant photo toxicity [14, 19].

CONCLUSION

The utilization of bioenergy is gaining popularity as a renewable energy source that has the potential to address the issue of rising energy costs. Additionally, it may provide a source of income for the farmers and rural communities across the globe. Bioethanol derived from residual biomass of agriculture offers significant environmental, socioeconomic, and strategic advantages. It is a viable and cleaner substitute for conventional fossil fuels, and can be regarded as a secure liquid fuel alternative. Using an ethanol-gasoline blend, an experimental investigation was conducted on a light-duty portable generator to improve engine performance, reduce hazardous emissions, and meet bio-sustainable norms.

- The particular fuel consumption of an engine can be reduced by as much as 28% depending on the blend, and ethanol is mostly responsible for this effect. Ethanol has a maximum thermal efficiency of 26% at full load.
- The unburned hydrocarbon volume was reduced by between 3% to 11%. Increased combustion and better lean-running engine performance from ethanol blends can lead to a 6-23% decrease in carbon monoxide emissions.

In order to achieve bio-sustainable aims, this research summarises ethanol's potential as an alternative fuel for portable generators. Overall, the use of bio-ethanol can provide a number of environmental benefits compared to traditional fossil fuels. The diversification of the energy mix can potentially decrease reliance on fossil fuels, particularly for nations that import oil. The creation of new markets and job opportunities for farmers, rural communities, and biofuel industries can be facilitated by them. In addition, they have the potential to decrease energy expenditures and enhance energy availability in geographically isolated or economically disadvantaged regions.

CONFLICT OF INTEREST

The authors declare no potential conflicts of interest regarding the research, authorship and/or publication of this article.

DATA AVAILABILITY

The data used to support the findings of this study are included within the article.

AUTHOR'S CONTRIBUTIONS

All authors are contributed equally to bring out this article.

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