Covenant Journal of Engineering Technology (CJET) Vol.5 No.1, June, 2021
ISSN: p. 2682-5317 e. 2682-5325 DOI: xxxxxxxxxx

An Open Access Journal Available Online

Emission Comparison of Air-Fuel Mixtures for Pure Gasoline and Bioethanol Fuel Blend (E20) Combustion on Sparking-Ignition Engine

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Received: 18.02.2021 **Accepted: 01.05.2021** **Published: 31.06.2021**

Abstract: This study analyses and compared the exhaust gas emission of two different air-fuel mixture, Pure Gasoline and Bioethanol Fuel blend (E10 and E20), in a spark-ignition (S.I.) engine. Proximate and ultimate analyses of pure gasoline and bioethanol blend were carried out for their respective percentage (%) elemental composition for each fuel (i.e., carbon, hydrogen, oxygen, sulphur, nitrogen, metals, and water). The analysis reveals that pure gasoline has high carbon (C) content of 86%, and bioethanol has a carbon content of 52.2%. Oxygen content stands at 33-35% and was carried out at varying load conditions. To ascertain their CO., CO_2, HC., NO, lambda, and the calorific values of exhaust emission. The result clearly shows that bioethanol's calorific value is lower than that of gasoline, which gives a remarkable increase in mechanical efficiency, which was attributed to an increase in the oxygen content in bioethanol, ethanol blend during combustion gives an air-fuel mixture lean in an unmodified engine. Hence the mixture strength (charge) burns more rapidly. Bioethanol blends in gasoline engines reduce CO. emissions, unlike gasoline, which gave higher CO emissions. The gas emission test was conducted on E10, and E20.and effective combustion was determined and completed much earlier in the expansion stroke, thereby decreasing the probability of CO emissions due to flame quenching. At the end of the investigation, it was found that bioethanol blend reduces CO and HC in exhaust stroke by 40% and gives a higher compression ratio (high speed) thus, causes a decrease in CO_2 NO_X. E20 for both idle and high speed recorded a remarkable reduction in comparison. Therefore, bioethanol fuel blends in gasoline engines are recommended as mitigation against the greenhouse gas effect.
Keywords— Bioethanol fuel blend; the calorific value of blend; exhaust gases; emission; and petrol engine

1. Introduction

Due to the growing industrialization and the expanding transportation sector worldwide, increasing demand for energy, specifically fossil-oriented energy. The world energy consumption is expected to increase to 180,000 GWh/year by 2020 [1]. Extensive use of fossil fuels over the years has resulted in increased prices of petroleum and electricity as well as a negative impact on the environment resulting from increases in greenhouse gas (GHG) emissions [2]. It is estimated that 81% of the world energy requirement utilization is obtained from fossil fuels [3].

Thus, the limit of fossil fuel reserves is quite clear. Global warming is growing. The increasing demand of crude oil (gasoline/diesel) is escalating by the day. The emission regulations are rhythm out from its utilization. Gasoline is a refined product of petroleum consisting of a mixture of hydrocarbons, its composition widely varies depending on the crude oils, gasoline is the second product to be extracted from crude oil by heating to boiling point of 110^{o}c.

Flammable liquid, transparent liquid primarily used as a fuel in most spark ignition (SI) engines. EIA (2020), it remains the world most important source of energy today. Due to its chemical contents mainly BTEX it as many harmful effects (environmentally) [3]. Alternatively, biofuel (bioethanol and biodiesel) is being perpecturateted to reduce the gassy emissions regimen. Studies have been reported on the application of bioethanol on S.I. and CI engines, which is the focus of these studies, and it is based on three aspects [4-5]. The application methods of bioethanol on petrol engines, fuel properties of bioethanol-gasoline blends, and out-there on the combustion and its resulting emission characteristics. To minimize the over-reliability of oil and contribute to the raising efforts of decarburizing the transport sector. Bioethanol fuel (ethyl alcohol) is a clear burning alternative fuel made from feedstock (wood, corn, cassava, sugar cane, vegetable matters, animal fats, to mention but a few) it is oxygenated (high oxygen content) with high octane rating and naturally burns, it can be renewed again and again without depleting its original source

Ethanol is a biodegradable and sustainable energy of organic chemical compound comprising of hydrogen, carbon and oxygen. It is a clean and clear liquid that looks like water (colourless), completely miscible with water [25]. Bioethanol has a somewhat sweet flavour when diluted with water which is part of its resource base, its pungent, and naturally denotes, with burning taste when concentrated, odourless, it is more volatile than water, flammable, burns with a light blue flame, and has excellent fuel properties for spark ignition internal combustion engines. Biofuels also have the budding/latent to minimize CO., HC., $NO_{X,}$ and chapped emissions resulting from combustion in comparison a liter of ethanol contains about two-thirds as much energy as a liter of gasoline. [21] However, pure ethanol has high octane value, which improves the performance of gasoline when blended and reduces the likelihood of engine knock problems, which occurs when fuel combusts too soon in an engine cylinder when a vehicle is working hard to accelerate. Since ethanol molecules contain (oxygen) unlike gasoline molecules ethanol fuel is referred to as "oxygenated". The oxygen in ethanol can improve the fuel combustion process thereby reducing emission such as carbon monoxide, ozone from unburned hydrocarbons, car inorganic particulates amongst other [21].

However, for related reasons, ethanol combustion reacts more with atmospheric nitrogen, which can marginally increase emissions of ozone-forming nitrogen oxide (NO_2) gases. It also contains a negligible amount of Sulphur compared to petroleum, blending ethanol with gasoline helps to reduce the sulphur content. However, even at high concentrations of ethanol, minimal amounts of water will draw the ethanol out of the blend away from the gasoline. Ethanol and gasoline are very similar in specific gravity. The two fuels mix readily with minimal agitation, since the biomass used to produce ethanol is created by photosynthesis and the carbon dioxide formed by the combustion of ethanol is recycled back to the air. The net reduction in greenhouse gases related to ethanol's displacement of petroleum fuel can vary substantially depending upon the amount of fossil fuel used in the ethanol fuel production process. Therefore, bioethanol produced through fermentation or synthesis provides a way of shifting to low-carbon, non-petroleum fuels, and chemical catalysts [6]. While improving vehicle efficiency is by far the essential low-cost way of reducing carbon dioxide (CO_2) emissions in the transport sector. Biofuels also have the potential to reduce C.O., H.C., NOx, and particulates emissions [7]. There are many parameters available in automobile engine that determines performance and emission of an engine. First is to determine the yield process and desire combustion quality, (required standards) and secondly is to give maximum output power requirements. The investigation indicated a considerable reduction in smoke and NO level. This was accompanied by an increase in brake thermal efficiency at high output, ignition delay and pressure rate went up. The rate of heat release in the premixed burn period was higher, when oxygen concentration in the intake was enhanced by 25% step up along with the use of water diesel emulsion the brake thermal efficiency improved and there was a further reduction in smoke level HC and CO levels also dropped alongside with NO emission went up due to temperature increase and oxygen availability. The variable compression ratio on a spark-ignition engine is designed to run on pure gasoline and ethanol-gasoline blend based on different ratios (EER) 10% and 20% by volume. In comparison with Manoel et al. [8], where a Binary search algorithm was used to determine the level of emission, and Ejilah et al. [9] reported a multicommuted flow analysis approach on TD110-115 Petrol Engine to engulf with an SV-5Q motor vehicle silencer gas analyser was used to determine the influence of fuel blends samples and lambda on heat and emissions of a petrol engine base on different loadings on the effect of lambda, silencer gas temperature, heat loss in the engine, and silencer gas analysis.

2. Materials and Methods

2.1 Preparation of Gasoline Ethanol Blend

The synthesis of catalysts and bioethanol production by the non-conventional method has earlier been reported [10]. A given volume (four litres) of unleaded gasoline sourced from Total Nigeria and AYM Shafa Plc were blended with half a litre. One litre of bioethanol produced from cassava using a non-conventional method (the use of synthesized heterogeneous catalyst) in a beaker marked E10 and E20 (10 and 20 percent by a ratio of the bioethanol to 90 and 80 percent of petrol, respectively). The blend was stirred continuously for a quarter of an hour at room temperature to attend a homogenous state and ensure relative phase stability and consistency of the blend on short-term measure. The choice of EER blend (E10 and E20) adopted for this study is in line with the U.S (FFR) [11].

2.2 Proximate and Ultimate Analysis

SV-5Q Automobile gas analyser was used to carry out the proximate and ultimate analysis. The equipment model, TD110-115, 45kg net weight with CR of (compression ratio) 20.5:1, temperature between 5 – 40 ^{0}C, humidity < 95% atmosphere and pressure was set at between 60-106 KPa. Fuel moisture was first carried out by weighing a required quantity of the sample, which was subjected to heat at103°C in an oven, then allowed for cooling. It was then reweighed. This analysis was to guarantee complete drying of the sample, and the procedure was repeated until its weight remained constant. The variance in the weight between the dry and fresh sample gives the moisture content in the fuel, and subsequently, readings of other various elemental compositions in the bioethanol, gasoline, and its blend was recorded. This is in line with [12-13].

2.3 Engine Exhaust Gas Emission Analysis

Peugeot 406 Nigeria's four-stroke internal combustion engine (E10 model) was used to investigate gas emission analysis on ethanol energy ratio (EER) of E10, E20, and pure gasoline fuel additives to determine engine performance. Furthermore, the comparative analysis for air-fuel mixture exhaust gas emission based on technical specifications was carried out; which is in agreement with the standard of SAE practice SAE J1312 for the four-stroke engine. The process was carried out on each of the three EER blends for idle and high-speed loadings, respectively, as in Plate 1.

The vehicle in which the analysis was carried out was placed (parked) on a computerized weighbridge. The emission analyser code was inserted in the exhaust. While the engine remained running (under all loads) the respective emission elements (calorific value (air/fuel ratio), lambda, H.C. (ppm), CO%, CO_2%, O_2% and NO in ppm) were displayed on the monitor of the computer for reading/recording. The results were recorded for each fuel sample for both idle and high-speed load (Tables 1 to 4). At the same time, a comparison was made manually based on the results obtained and the benchmark of the gasoline test, in agreement with the standard of SAE practice SAE J1312, in agreement with Abdulkarim et al. [14] and Artur et al. [15].

a b c

Plate 1: Gas Emission Test device and the test

3. Results and Discussion

In this section, the investigational results of emission and its comparison for fuel-air mixture combustion for pure gasoline and gasoline bioethanol blend on the pollutant emissions emitted from the engine are reported and discussed. It must be brought up here that Ethanol Energy Ratio (EER) represents the ratio of ethanol blend.

2.1 Proximate and Ultimate Analysis of Raw Ethanol Produced

Proximate and ultimate analysis carried out to determine various elemental compositions of the three fuels; (pure gasoline, pure ethanol, and gasoline-ethanol blend (E10 and E20) with particular reference to oxygen, carbon, and hydrogen content of their respective fuels combustion and emissions comparison. It was observed that pure gasoline contains 86% carbon and oxygen 0%, compared with bioethanol and its blend, which contains 50.10% – 52.20% of carbon and 33.35% - 34.80% oxygen (Figure 1). H.C. and C.O. are products of incomplete combustion or inappropriate catalytic converter from pure gasoline combustion, which results from flame quenching on the surface of the piston crown containing a high carbon percentage.

Moreover, oxygen deficiency could result in incomplete combustion and subsequent power loss. Therefore, resulting in carbon monoxide formation compared with bioethanol blend. This gives better combustion developed from lean fuel mixture with high oxygen content, as shown in Figure 1.

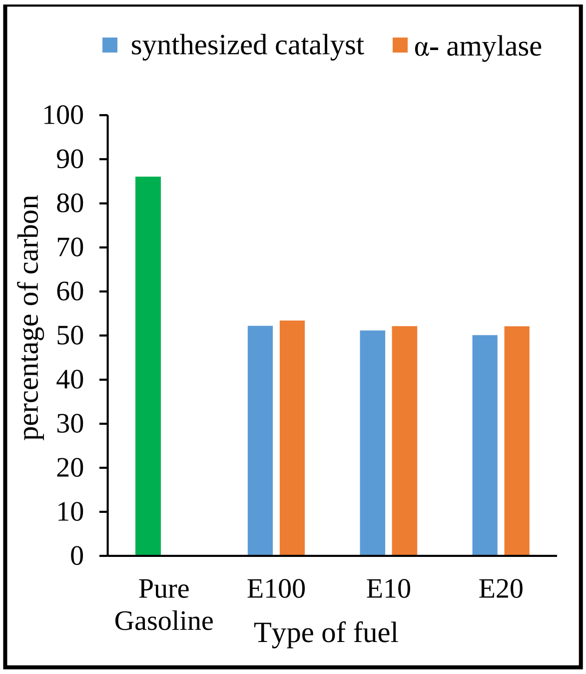

Figure 1: Carbon Content in Pure Gasoline and the Fuel produced using synthesized catalyst and α-Amylase

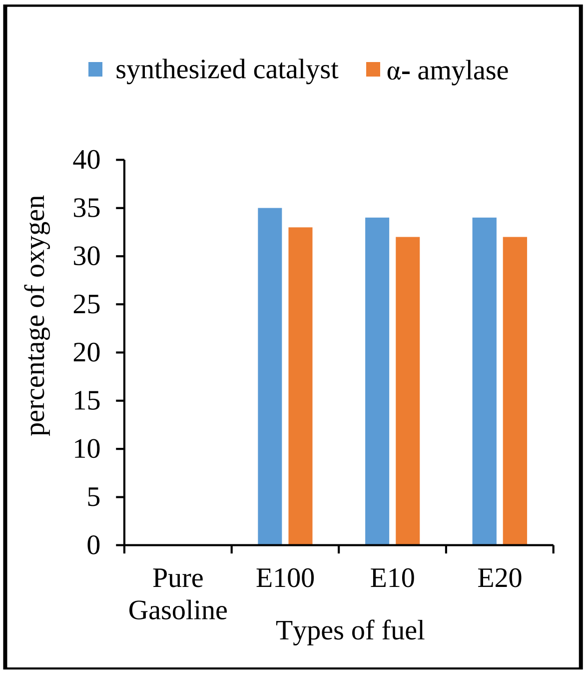

Figure 2: Oxygen Content in Pure Gasoline and the Fuel produced using synthesized catalyst and α-Amylase

The carbon monoxide focus diminishes as the EER mix builds due to the expansion of bioethanol, which is exceptionally oxygenated. Making the combination slenderer and gave better ignition with less C.O. creation. Figure 2 portrays the rates of oxygen present in the various energizes by close and extreme examination. This is in concurrence with Haroun et al. [16] discoveries. The H.C. emanation diminishes with the expanding EER mix. Rapid outcomes in stable ignition measures and quicker fire, along these lines, discharges fewer outflows after burning on account of its higher octane rating, which has the chance of motor thump event. High oxygen content in bioethanol additionally lessens nitrogen oxide emanation from the ignition, higher warmth vaporization, and fire speed. It gives more oxygen to the ignition cycle prompting a "learning impact" in adaptation [17].

When contrasted with conventional unleaded gas, bioethanol gives clean-consuming and without particulate fuel when combusted. The final result is carbon dioxide and water. The NOx focus relies on burning temperature, accessibility of oxygen (lambda), and better ignition time. The NOx increments as the EER mix increments close by with load increment. This is because of a superior burning cycle because of a higher ignition temperature, which favours NOx development. As motor speed was expanded, the NOx discharges for all mixing proportions were additionally slowly expanded. Unadulterated fuel during the burning cycle for a complete transformation of carbon and hydrogen, lacking oxygen was challenging to accomplish, prompting particulates and carbon monoxide exhaust discharge. Hence, oxygen-enhanced ignition is essential and a critical factor for contamination control and improved motor burning; this is in confirmative [18].

2.2 Engine Exhaust Gas Emission

Tables 1 to 4 showed the gas emission test, C.O., and CO_2 emissions and were compared for all fuel mixtures as depicted in Figure 3 and 4. It was seen that the bioethanol mix is reasonable at all heaps because lesser carbon monoxide outflow was recorded contrasted with unadulterated gas. Base on the examination in this investigation, bioethanol at 10% and 20% by volume are better at all heaps, and high-pressure proportions were accomplished; this is in arrangement [19].

Table 1: Gas Emission Test Result for Pure Gasoline: IDLE SPEED

Gas Emission Test	Max.	Min.	Average	Status
HC (ppm)	201	443	332	X
CO (%)	0.75	2.05	1	V
Lambda	1.01	1.07	1	V
CO_2 (%)	11	13	12	
O_2 (%)	0.9	0.99	0.94	
NO (ppm)	171	788	479.5	

"X" refers to incomplete combustion for idle speed loading for all cases of H.C. emission. At the same time, C.O. represents inappropriate combustion resulting from catalytic converter or oxygen deficiency. Also, "V" means complete combustion in all loading.

Table 2: Gas Emission Test Result for Pure Gasoline: HIGH SPEED

Gas Emission Test	Max.	Min.	Average	Status
HC (ppm)	201	391	269	X
CO (%)	0.73	2.87	1.8	X
Lambda	0.97	1.07	1.02	V
CO_2 (%)	11	13	12	
O_2 (%)	1.65	1.72	1.68	
NO (ppm)	84	341	212.5	

Table 3: Gas Emission Analysis Test for Bioethanol Blend (E20): IDLE SPEED

Gas Emission Test	Max.	Min.	Average	Status
HC (ppm)	168	334	260	X
CO (%)	0.51	1.69	1	V
Lambda	0.96	1.01	1	V
CO_2 (%)	10	12	11	
O_2 (%)	1.69	1.75	1.72	
NO (ppm)	84	380	232	

The investigation carried out from the experimental analysis in this study shows that the engine performance increased. And pollutant emission was decreased using bioethanol–gasoline blend in an S.I. engine against pure gasoline (Figure 5).

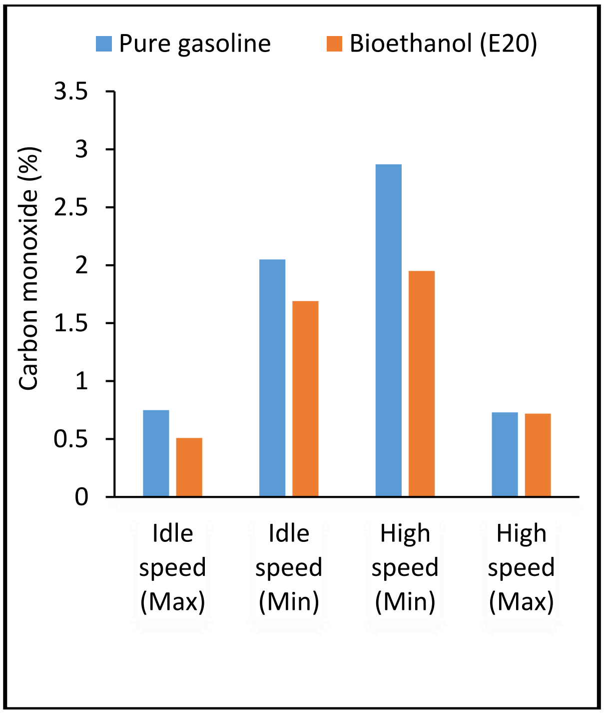

Figure 3: Gas Emission Test for Carbon monoxide at Idle and High Speed

There are many parameters available in automobile engine that determines performance and emission of an engine. First is to determine the yield process and desire combustion quality, (required standards) and secondly is to give maximum output power requirements. The investigation indicated a considerable reduction in smoke and NO level. This was accompanied by an increase in brake thermal efficiency at high output, ignition delay and pressure rate went up. The rate of heat release in the premixed burn period was higher, when oxygen concentration in the intake was enhanced by 25% step up along with the use of water diesel emulsion the brake thermal efficiency improved and there was a further reduction in smoke level HC and CO levels also dropped alongside with NO emission went up due to temperature increase and oxygen availability.

The results reveal that when bioethanol was blended, the heating value of the blended fuel decreased, this result is in line with [20-22]. At the same time, the octane rating increased. This implies that lambda (air-fuel ratio mixture for the combustion process is normal), confirmative with standard specification.

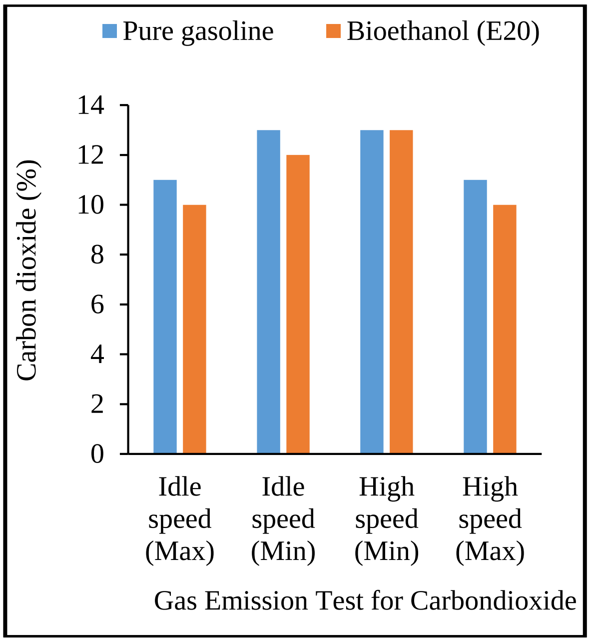

Figure 4: Gas Emission Test for Carbon dioxide at Idle and High Speed

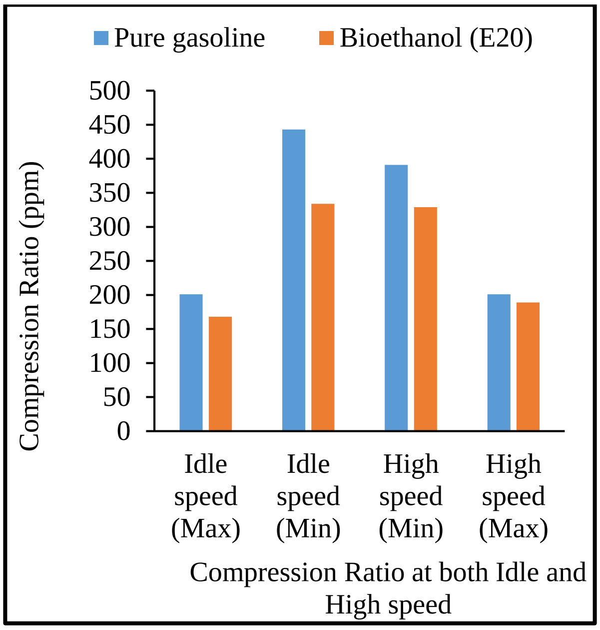

Figure 5: Compression Ratio for both fuels at both Idle and High speed

And must not exceed "1" as recorded for ethanol blend as well as" 1.07" as recorded for pure gasoline (Figure 6). In contrast, CO_2 emission from ethanol blend recorded 10% as against 13% for pure gasoline and HC. for ethanol blend 168 ppm against 201 ppm for gasoline for idle speed loadings. Where "V" represents complete combustion in all cases, from Table 4, it could be observed the increase in EER has improved for all exhaust emission of the elements (HC., CO, and Lambda). Furthermore, as the motor forces increases and transparent fuel utilization diminishes, and CO. emanation from the motor reductions. Because of the inclining impact brought about by the expansion of bioethanol HC. discharge. The results also show that there were decreases in similar working conditions of the CO_2 release from oxygen and water reduction on account of the improved burning [20], [23-25]. The life cycle of SI engine also depends on the ethanol blend for maximum performance all through the life span [27-30]. This analysis will assist the manufacturing industry to produce quality fuel blend that will reduce environmental pollution thereby improving the economical of the nation.

Table 4: Gas Emission Analysis Test for Bioethanol Blend (E20): HIGH SPEED

Gas Emission Test	**Max.**	**Min.**	**Average**	**Status**
HC (ppm)	189	329	259	V
CO (%)	0.72	1.95	1.34	V
Lambda	0.96	1.01	0.99	V
CO_2 (%)	10	13	11.5	
O_2 (%)	0.85	0.91	0.88	
NO (ppm)	158	760	459	

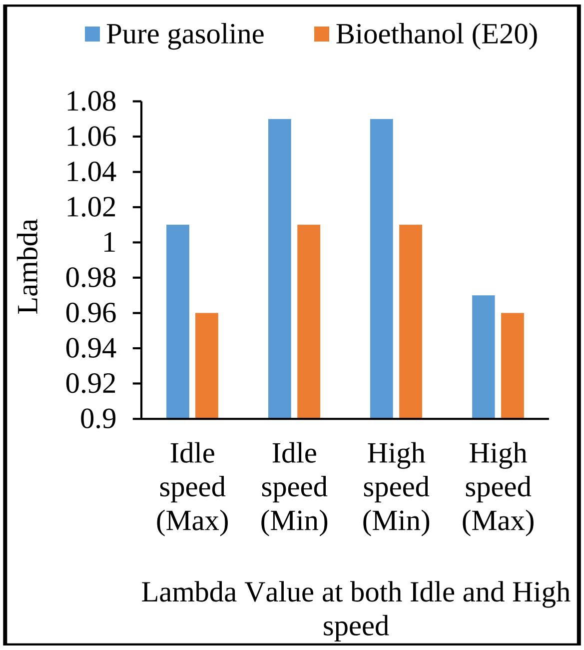

Figure 6: Lambda Value at both Idle and High speed

4. Conclusions

The investigation revealed from the proximate and ultimate analysis that pure gasoline has high carbon (C) content of 86%, compared to bioethanol with a carbon content of 52.2%. In comparison, higher exhaust emission of carbon dioxide was recorded when pure gasoline was combusted, resulting in greenhouse gas and global warming. In contrast, a remarkable decrease in emission was recorded using a gasoline bioethanol blend for combustion, which will contribute to the transport sector's decarbonisation if implemented. The result reveals that bioethanol blends (E20) status indicate complete combustion, which is quite suitable in replacing pure gasoline in the transport sector

It was also observed that the concentration of bioethanol increases alongside with reduction in lambda. In contrast, gasoline fuels were found to have the lowest silencer temperature output under the same conditions. The increase in EER blends concentration (E10 and E20) shows a remarkable higher trend. Due to their higher tendency from oxidation, lower C.O. emission was recorded in the blends than gasoline during the combustion process.

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