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Performance evaluation of *Moringa Oleifera* biodiesel synthesized from cow bone catalyst and its blends in diesel engines

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Abstract

Performance evaluation of Moringa oleifera biodiesel synthesized from cow bone catalyst and its blends in diesel engine has been studied. The research work is aimed at comparing the performance of petroleum based diesel fuel and directly cracked triglycerides (biodiesel) produced from moringa oleifera oil obtained from northern Nigeria. The performance evaluation was conducted using BD100, BD80, BD60, BD40 and BD20, this is to evaluate the performance of the diesel engine in terms of brake thermal efficiency (BTE), brake specific fuel consumption efficiency (BSFCE), carbon monoxide (CO), oxides of nitrogen (NOx) and oxides of sulphur (SOx) emissions. BD blends recorded higher brake thermal efficiencies relative to petroleum based diesel fuel. BD100 and all the blends under study recorded 16.67 % BSFCE lower than that of diesel fuel at optimum engine load. For all the sample fuels under study, decrease in the amount of CO is directly proportional to the engine load. The result of study shows that the NOx emissions increase with corresponding increase in engine loads. For all the sample fuels under study, negligible increase in the amount of SOx is directly proportional to the engine load and vice versa.

Keywords: Performance Evaluation, Moringa Oleifera, Biodiesel, Catalyst, Blends.

Introduction

The quest for vibrant and sustainable industrial, power and transportation sectors development can only be attained through decelerating the hiking cost of petroleum diesel; the fact that it is at the forefront of posing economic burden to the developing countries, Nigeria inclusive. Annually, large percentage of our budget go to the importation of diesel, which is a live wire for industries, power and the transportation sectors of the economy. The use of petroleum diesel by the teaming population of industrial, power and transportation sectors of the global economy has been the major factor behind the generation of greenhouse gases, which in turn leads to the concept of global warming[1]. CO_2, CO, NOx and SOx are the major causes of drought in addition to other flora and fauna environmental adversities[2].

On the other hand, biodiesel is proved to have tremendously cut down the generation of greenhouse gases by 75.00-83.00% relative to petroleum diesel[3]. Similarly, biodiesel is not toxic in nature, as such, it is deemed useful and necessary for transportation in sensitive environments–mining loops and marine environments, largely because the combustion of neat biodiesel has proven to have reduced CO, particulate matter and unburned hydrocarbon emissions by 46.70%, 66.70% and 45.20% respectively[4-7]. In the same vein, further lends credence on *moringa oleifera* seed oil as a reliable source for production of biodiesel when consideration was made for poor countries with large expanse of arid lands such as the Northern part of Nigeria[8]. By implication, it is easy to grow *moringa* on a large scale and as such minimize the cost of production of biodiesel from *moringa* on an industrial scale.

There exists the potential for a 90.00 % yield of biodiesel from *moringa* seed oil with a yield per seed potential of about 38.10 %[9-10]. The need to explore further potentials of the *moringa* seed oil in biodiesel production therefore, cannot be over emphasized. The potential for huge production of renewable fuel from *moringa* seed without jeopardizing the food security of developing nations and within the limits of resource availability makes *moringa oleifera* a research interest worth exhaustively studying, hence, the need for this study.

Materials and methods

Naturally aspirated compression ignition diesel engine with specifications shown on Table-1 was used to carry out the experiment.

The evaluation tests were carried out using BD20, BD40, BD60, BD80, BD100 produced from *moringa oleifera* seed and characterized by Ameh, C. U.[11] and Automotive Gas Oil (AGO) bought from Nigerian National Petroleum Cooperation (NNPC) Mega station, retail outlet in Minna, by direct injection.

Table-1: Diesel Engine Specifications.

Manufacturer	Perkins
Model	AD 3.152
Volumetric Efficiency at Room Temperature	90%
Number of Nozzles	3
Number of Holes per Nozzle	4
Brake Mean Effective Pressure	7.157 bars
Maximum Engine Power at 1500 rpm	27.00 kW
Bore	91.40 mm
Stroke	127.00 mm
Compression Ratio	18.5:1

Methodology: Prior to the performance evaluations tests, the diesel engine was run with diesel (AGO) fuel for 30 minutes[12] at a speed of 1000rpm, measured by a digital Tachometer. The engine was then connected to a power supply from a 33 KVA generator having a power factor 0.90 and a varied efficiency of 90–95%. The exhaust of the diesel engine was connected to the gas analyzer (V402-01). When the experiment was completed with diesel, BD20, BD40, BD60, BD80, BD100 produced from *moringa oleifera* seed was the used to run the engine. Average readings of the repeated test were then taken and used for calculation and analysis.

Performance parameters such as brake thermal efficiency, brake specific fuel consumption efficiency, Carbon monoxide (CO) emission, Nitrogen oxide (NOx) emissions and Suphur oxide (SOx) emission were then determined. Figure-1 depict the setup for the experiment.

Results and discussion

Performance evaluation of the diesel engine from *moringa oleifera* biodiesel synthesized from cow bone catalyst and its blends cut across experiments carried out between 10 to 90% engine loads. At each and every diesel engine load, experiments were conducted using diesel blends (B20, B40, B60, B80 and B100) and petroleum based diesel (AGO) fuel. Moreover, the effects of biodiesel blends on the loads (brake thermal efficiency and brake specific fuel consumption efficiency) and greenhouse gases emissions (CO, NOx and SOx) were investigated.

Brake Thermal Efficiency (BTE): Figure-2 depicts the percentage BTE against engine load for the performance evaluation of diesel engine from *Moringa Oleifera* based biodiesel and its blend. It is deduced that increase in percentage engine load is proportional to the increase in the brake thermal efficiency up until 80.00%. This phenomenon is attributed to efficient combustion and lesser losses at higher percentage engine loads[13]. On the other hand, and above 80.00% engine load, decreases on this phenomenon was observed for all the samples under study. Moreover, lower brake thermal efficiencies observed for all BD sample at 10 to 40.00% engine loads may be attributed to incomplete combustion[14]. The maximum and minimum brake thermal efficiencies observed are 5.30% at 10.00% engine load and 31.00% at 90.00% for BD100, 80, 60, 40, 20 and BD100 at 90.00% engine load respectively. Comparing the brake thermal efficiencies at higher percentage engine loads, it is observed that the BD blends recorded higher brake thermal efficiencies relative to petroleum based diesel fuel. BD100 recorded the highest percentage thermal efficiency compared to the blends; with BD80 showing close proximity. A BTE greater than that of AGO (diesel fuel) by 14.81% was observed at optimum engine load for BD100 while 11.11%, 7.41%, 3.70% and 0.00% were recorded for BD80, BD60, BD40 and BD20 respectively. The findings of this study are in agreement with the findings of different reserchers[14-15]. It is conveniently deduced that BD100 and BD80 could be used in diesel engines without modifications.

Figure-1: Experimental Setup for the Performance Evaluation.

Brake Specific Fuel Consumption Efficiency (BSFCE): The BSFCE of a fuel has been mathematically defined as the ratio of mass flow and effective power[14]. BSFCEs of diesel engines largely depend on the relationship between the density of the fuel; its viscosity; its heating value and its volumetric fuel injection system[14]. Principally, biodiesel fuel is often fed into diesel engines on volumetric bases per strokes; therefore, this phenomenon necessitates feeding the engines with reasonable amounts biodiesel. This becomes imperative the fact that biodiesels have low calorific values relative to petroleum diesel[16-17]. Figure-3 depicts the brake specific fuel consumption efficiency against percentage engine load. It can be seen that increase in load, leads to decrease BSFCE down to 60.00% load and then becomes steady for all the biodiesel samples under study contrary to the findings of Ameh, C. U.[11] who reported an increase in above 70.00% load. The variation may be attributed to the use of conventional transesterification method involving methanol and the variation of the feedstock used. It is also observed that at 10 to 60.00% engine loads, the BSFCEs of BD100 and all the blended samples under study are higher relative to petroleum diesel. The maximum and minimum brake specific fuel consumption efficiencies observed are 1.53KgKw^{-1}hr^{-1} at 10.00% engine load and 0.30KgKw^{-1}hr^{-1} at 90.00% engine load for BD20 and BD 100, 80, 60, 40 and 20 respectively. BD100 and all the blends under study recorded 16.67% BSFCE which is lower than that of diesel fuel at optimum engine load. This trend is attributed to the characteristic effects - densities, viscosities and heating values of the samples under study[16]. The result obtained is in agreement with the findings of Chauhan et al. [18].

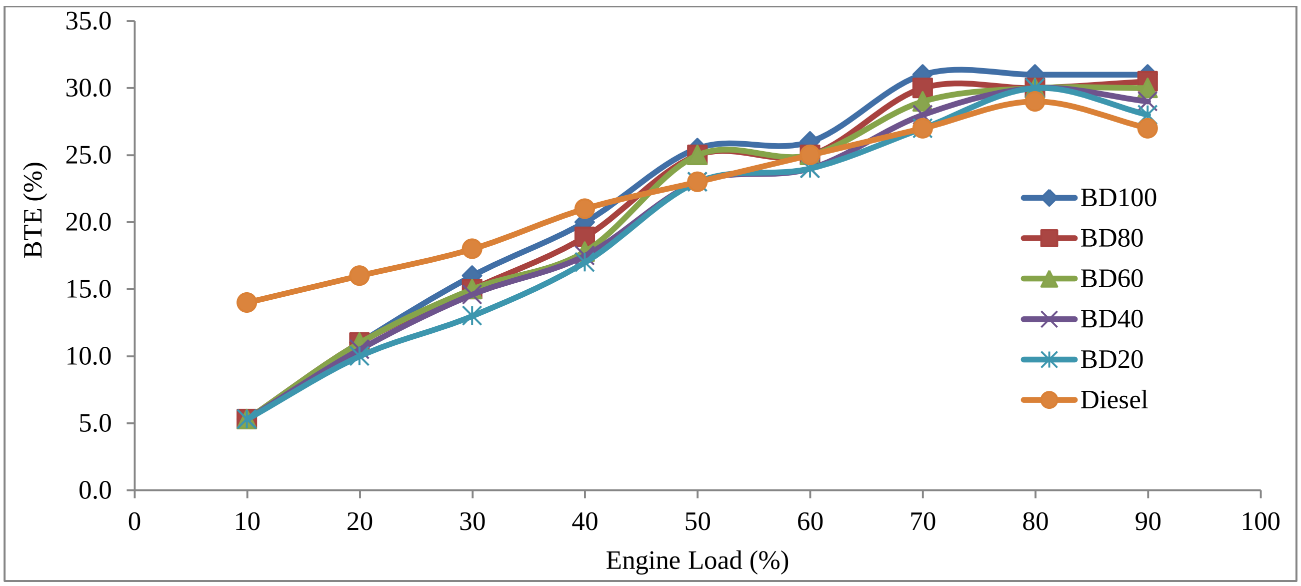

Figure-2: Percentage Brake Thermal Efficiency against Engine Load.

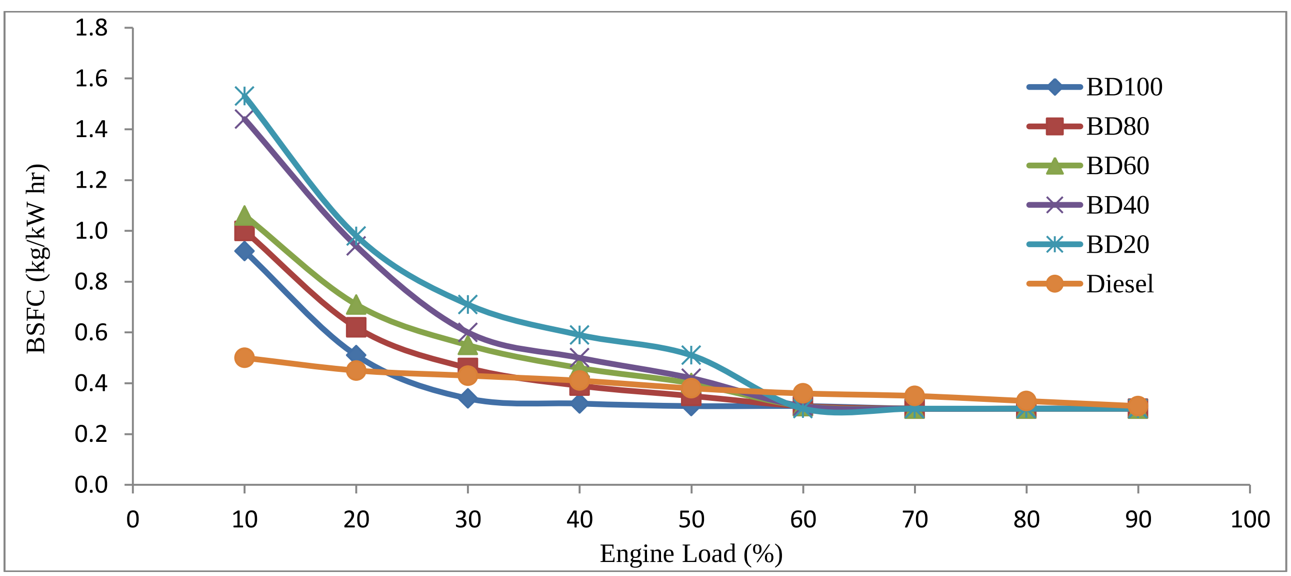

Figure-3: Brake Specific Fuel Consumption Efficiency against Percentage Engine Load.

Carbon Monoxide (CO) Emission: Figure-4 show variation in CO_2 emissions for all of the fuel samples at various loads. For all the sample fuels under study, decrease in the amount of CO is directly proportional to the engine load. The optimum reduced CO concentration levels observed at 20.00% engine load relative to diesel fuel are: 0.020%, 0.018%, 0.017%, 0.016% and 0.015% for BD100, BD80, BD60, BD40 and BD20 respectively. This phenomenon is attributed to the fact that elevated combustion temperatures coupled with elevated engine loads ultimately contribute to the observed CO degenerating trends therein. Similarly, it has been observed that CO emissions have greatly reduced with increase in percentages for all the blended samples under study. This trend is ultimately observed for BD100. This trend may be caused by high amount of oxygen present in biodiesel compared to petroleum diesel and oxygen is the only driving element that helps in completing the combustion processes of diesel engines[12]. The finding of this study is in agreement with the findings of Nicholas et al[19]. Environmental problem such as accumulation of carbon dioxide in the atmosphere is caused by production of carbon dioxide from combustion of fossil fuels[20]. Although biofuel combustion produces carbon dioxide and its absorption by crops helps to maintain CO_2 levels constant[20].

Nitrogen Oxides (NOx) Emission: Figure-5 presents variation of NO emissions for the diesel and biodiesel blend fuels with corresponding engine loads. It can be seen that NOx emissions increase with corresponding increase in engine loads. On the basis of comparisons, NOx emissions for all the biodiesel blends increase greatly at 20.00, 40.00, 60.00 and 80.00% engine loads. Optimal emissions observed for BD100, BD80, BD60, BD40 and BD20 are: 498ppm, 546ppm, 557ppm, 568ppm and 587 ppm respectively. The trend observed in NOx emissions can only be attributed to the lean air-fuel ratio, because biodiesel samples of all origin contain 12.00% more oxygen in their molecular structures relative to diesel fuels. Consequently, the oxygenate BD blends caused increase in the observed NOx emissions (Figure-5). Here, the concept of complete combustion from all the BD samples at elevated temperatures is responsible for the formation of elevated NOx emissions observed[21]. The result obtained is slightly lower to the result put forward by Alireza, S.[22], this is attributed to the fact that conventional acidic and basic methods of methyl ester were used and the acidic cum basic residues are tantamount to affecting the final NOx emissions of the study.

Sulphur Oxides (SOx) Emission: Oxides of sulphur are also formed as a result of the incomplete combustion processes that occur in diesel engines. According to Shahid et al[13], SOx are pollutants and carcinogenic in nature. Some of the effects include irritation of the eyes and lungs cancers. Figure 6 depicts the patterns of SOx observed in diesel fuel, BD100, BD80, BD60, BD40 and BD20 respectively. For all the sample fuels under study, negligible increase in the amount of SOx is directly proportional to the engine load and vice versa. The minimum SOx concentration levels observed at 20.00% engine load relative to diesel fuel are: 0.11%, 0.17%, 0.23%, 0.28% and 0.33% while the optimum SOx concentration levels observed at 80.00% engine load relative to diesel fuel are: 0.41%, 0.45%, 0.47%, 0.49% and 0.51% for BD100, BD80, BD60, BD40 and BD20 respectively. This phenomenon is attributed to the fact that elevated combustion temperatures coupled with elevated engine loads ultimately contribute to the observed SOx generation trends. Similarly, it has been observed that SOx emissions has greatly reduced with increase in percentages for all blended samples under study. This trend is ultimately observed for BD100 and is attributed to the fact that biodiesel is made up of high amount of oxygen compared to petroleum diesel (AGO) and oxygen is the only driving element that helps in completing the combustion processes of diesel engines[14]. The finding of this study is in agreement with the findings of Shahid et al [13].

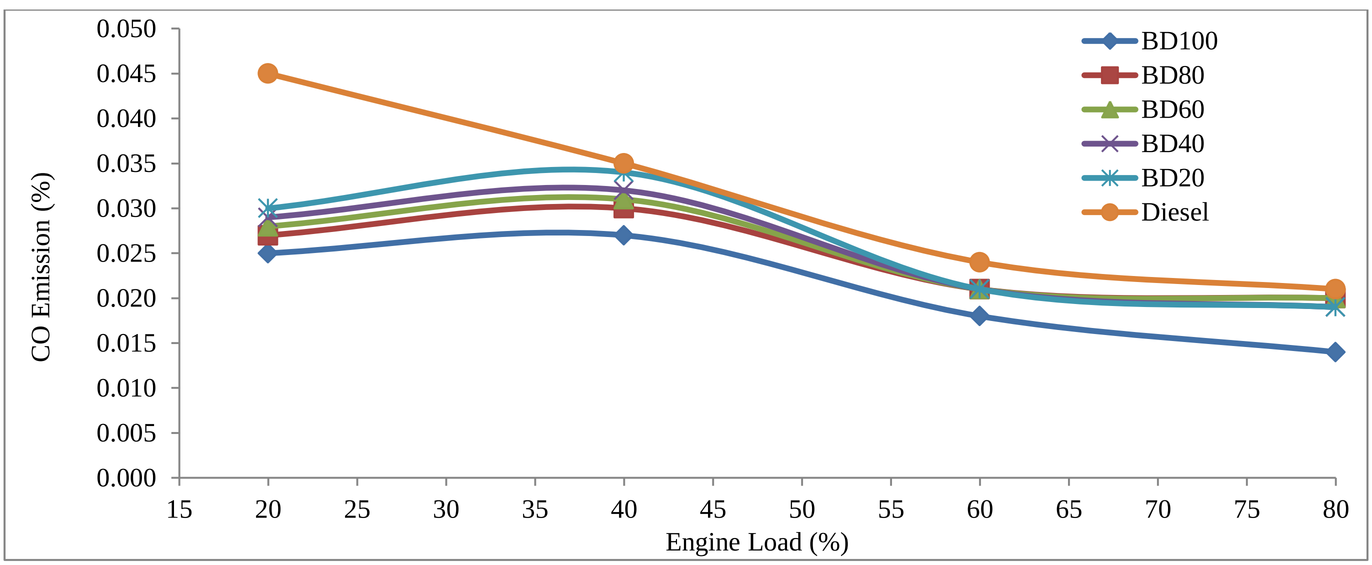

Figure-4: Percentage CO Emission against Engine Load.

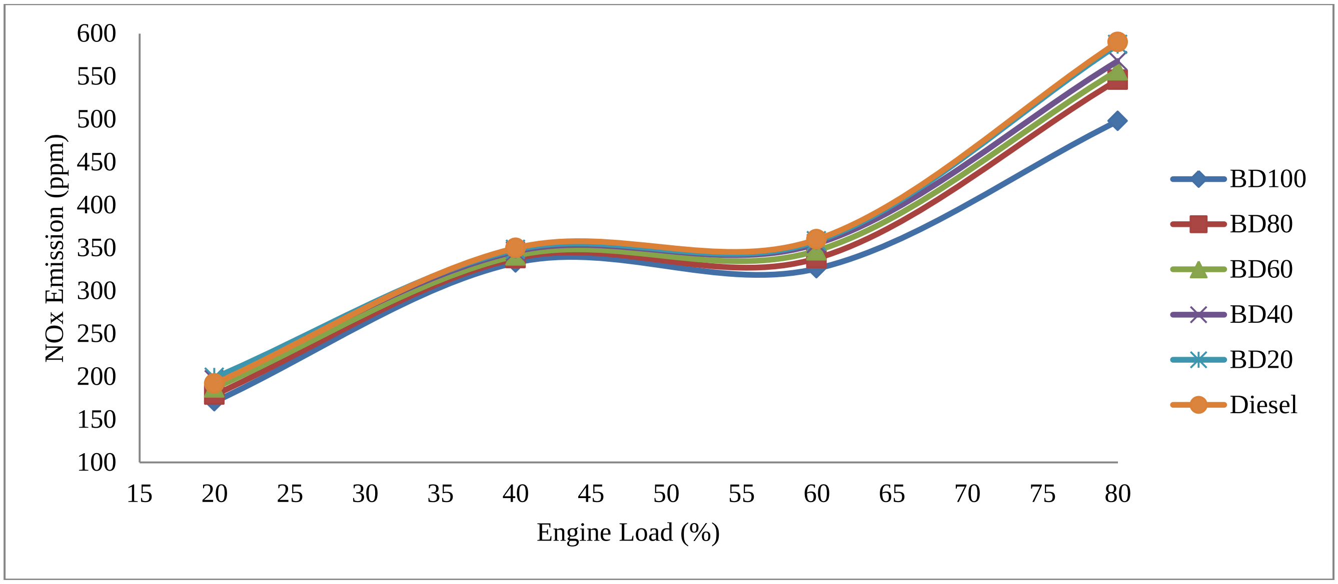

Figure-5: Oxides of Nitrogen Emissions against Engine Load.

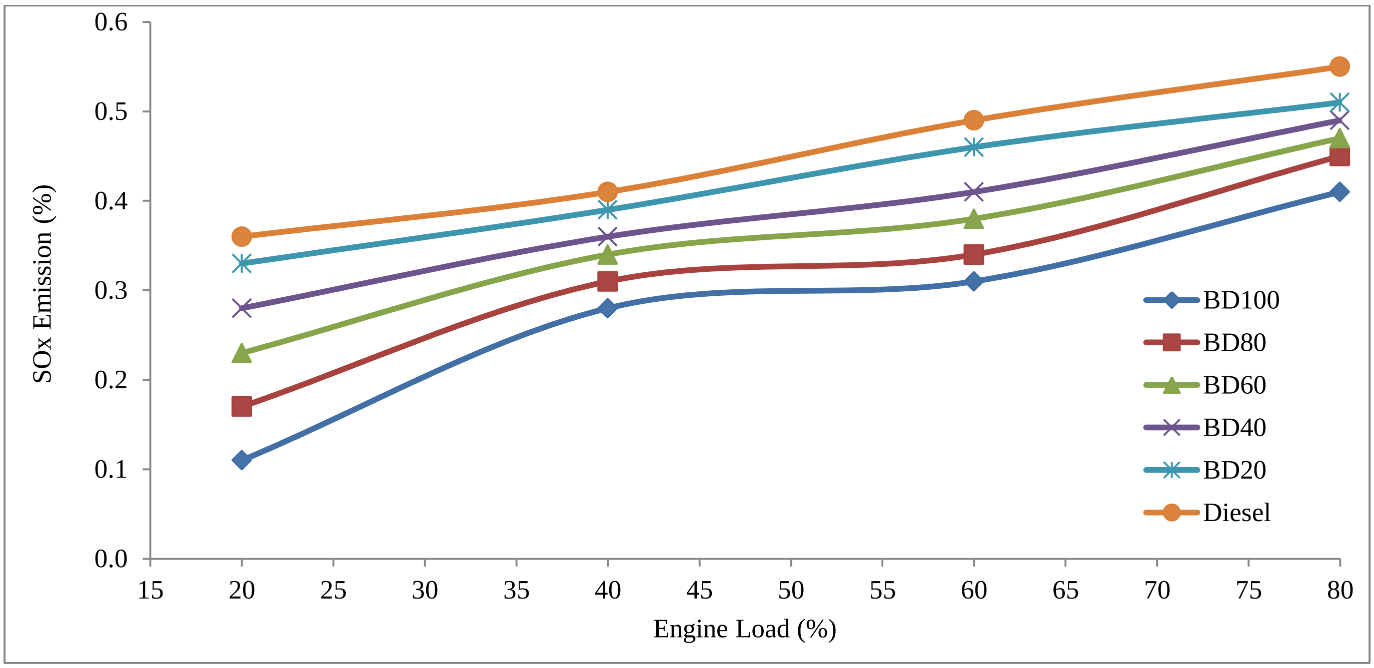

Figure-6: Oxides of Sulphur Emissions against Engine Load.

Conclusion

Research has been carried out on the performance evaluation of diesel engine from *Moringa Oleifera* biodiesel synthesized from cow bone catalyst and its blends. The biodiesel samples employed in this study were produced from virgin *Moringa Oleifera* oil. BD100, BD80, BD60, BD40 and BD20 were primarily employed for the performance evaluation tests. Effects of diesel engine loads in relation to BTE, BSFCE, CO, NOx emissions and SOx emissions were evaluated. BD blends recorded higher BTEs relative to Automotive Gas Oil (AGO). The blends under study recorded 16.67% BSFCE lower than that of AGO at optimum engine load. For all the BD samples under study, decrease in the amount of CO is proportional to engine loads. NOx emissions increase with corresponding increase in engine loads. For all the samples under study, negligible increase in the amount of SOx is directly proportional to the engine load and vice versa. Finally, the concentration levels SOx and NOx emissions recorded in the study are attributed to use of elevated temperatures of combustions, the chemicals employed in synthesizing the catalyst used and the increased concentration levels of oxygen in the combustion chambers.

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