# Evaluation of the Rate of Reduction of Greenhouse Gases from Diesel Engine Powered with Jatropha Curcas Seed Oil Blend Diesel

***Echebiri, Comfort C., **Nnodu, V. C. and **Onuoha, D. C.**
*Standards Organization of Nigeria, Old State Secretariat, Okigwe Road, Owerri.
**Environmental Management Department, Nnamdi Azikiwe University,
P.M.B. 5025 Awka, Nigeria.
Email: adakuechebiri@yahoo.com; chidave2k3@yahoo.com

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**ABSTRACT:** *As part of the effort to reduce greenhouse gases emissions and lower its negative effects on climate change, this study was conceived with the aim of evaluating the rate of reduction of greenhouse gases emission from diesel engine powered with Jatropha Curcas seed oil blend diesel. The study produced biodiesel from the oil extracted from the Jatrophha Curcas seed using trans-esterification method. The amount of $CO_2$, $SO_2$ and $NO_2$ emitted from a diesel engine powered with conventional oil and jatropha biodiesel blend were determined to ascertain whether there was reduction or increment in percentage of emissions. Laboratory analysis of Jatropha Curcas oil shows that 131.9524g jatropha curcas seed yielded 90.559ml of biodiesel and 41.2437ml of glycerol. Conventional diesel and Jatropha curcas biodiesel produced has similar physiochemical characteristics confirmed through ASTM(US) and DIN(EN) hence their combustibility. $CO_2$ emissions increased with increase in diesel at B100 and B50 while it decreases in B20 and B40. While $NO_2$ emissions increased by 1% in all the revolutions per minute, $SO_2$ was only detected at B100 and B50 emission of the greenhouse gases. From the questionnaire survey conducted at Egbema, it was found that gas flaring has serious adverse effect on vegetation in the area, significant negative effect on the economy of the area due to the rise in air pollution. The result of the laboratory experiments showed that blended green diesel reduces the emission of greenhouse gases from combustion of diesel. The study recommended adoption of renewable energy sources for the operation of the oil firms in Egbema the study therefore concluded that blended green diesel is a promising alternative fuel for internal combustion engines.*

**KEYWORDS:** greenhouse gases emission; biodiesel; jatropha curcas seed oil

## INTRODUCTION

Global industrial attention has been focused on cleaner and eco-friendly fuel products that are now labelled “green Fuel”. The utilization of liquid fuel such as biodiesel from vegetable oil by trans-esterification process represents one of the most promising options than the use of conventional fossil fuels. (Janahiraman, 2008). One of such vegetable oils is Barbados nut, Physic nut or *Jatropha Curcas* perennial oil seed bearing shrub. It is member of spurge family, with an average life span of 40-50 years, depending on prevailing climatic conditions. It has smooth grey back, which excludes white coloured, watery latex when cut. There are 170 known species world-wide of *Jatropha Curcas* which is also known as Physic nut tree, (Carels,2009; Dehgan and Webster, 1979).Interest in biomass is increasing in the light of the growing concern about global warming and resulting climate change. The emission of the greenhouse $CO_2$ can be reduced when "green" biomass derived transportation fuel such as biodiesel are used (Chmielwski, 2005). The idea that the fossil fuel reserves are limited, together with concerns over security of supply (the oil crisis), initiated the first up rise of interest in biomass and all other renewable energy forms in the 1970s.In the 1980s the concern grew that global warming and the resulting climate change from fossil fuels consumption known as crude oil reserves are estimated to be depletable in less than 50 years at the present rate of consumption.

The combustion of biodiesels has been reported to emit lesser pollutants, compared to diesel. Biodiesel is nearly carbon neutral, meaning it contributes almost zero emissions to global warming. Tran-esterification of vegetable oil was conducted as early as 1853, by scientists (Duffy and Patrick, 1853); many years before even the first diesel engine fuel dates back to 1893, when Dr. Rudolf diesel built the first engine with full intension of running it on vegetative source. Rudolf (1900) diesel's prime model, a single 10 feet iron cylinder with a flywheel at its base, ran on its own power for the first time in Augsburg Germany on august 10$^{th}$ 1893. In remembrance of this even, August 10$^{th}$ has been declared international biodiesel day. Rudolf displayed his engine at the world fair in Paris, France in 1990 and astonished every one when he ran the patented engine on peanut oil. He received the ‘‘grand prix’’. In a 1912 speech he said "the use of vegetable oil for engine fuels may seem insignificant today, but such oils may in the course of time become as important as petroleum and coal tar products of the present time *(*Divya and Tyagi, 2006).

**Statement of the Problem**

The combustion of petroleum diesel is known to increase greenhouse concentrations in the atmosphere, these fuels are likely sources of global warming. Another concern is advocated by the peak oil theory which predicts a rising cost of fossil fuels caused by a severe shortage of petroleum reserves underground during an era of continuous increase in its consumption. According to the peak oil theory, the demand and supply will continue to grow. Growth in population and industrialization has led to an increase in energy demand in Nigeria. Over the years, fossil fuels have been the major supply of energy, which about 90% being consumed as liquid fuel for transportation and energy generation (Devanesan, 2010). Fossil fuels are non-renewable and have led to global warming and environmental pollution. They cause obvious problems such as oil spills and smog filled air, acid rain, for example, caused particularly by sulphur in fossil fuel which damages buildings and harms trees, aquatic life and insects.

During combustion processes, different pollutants like fly ash, sulphur oxides ($SO_2$ and $SO_3$), nitrogen oxides ($NOx = NO_2$ and NO) and volatile organic compounds are emitted. These pollutants are present in the atmosphere in such conditions that they can affect man and his environment. Air and other pollutants not only act directly on the environment but contamination of water and soil leads to their degradation. Wet and dry deposition of inorganic pollutions lead to acidification of environment, a phenomena which affect the health of the people, increase corrosion, and destroy cultivated soil and forests, plant like coniferous trees are not resistant oxides and following longer exposure leaves wither and fall. Many cultivated plants are not resistant to these pollutants, especially in the early periods of vegetation (2005), Many authors like Nelson (2010), Nawa, *et al* (2019), Haziratul (2017) among others have worked on the production of jatropha curcas seed oil, but the rate of emission compared to that of the conventional diesel is yet to be investigated in Nigeria . Hence this work will focus on the rate at which greenhouse gases emitted when a diesel engine is powered with blend of refined *jatropha curcas* seed oil compared to when it is powered with the convention diesel, to ascertain the percentage rate of the greenhouse gases ($CO_2$, $SO_2$, and $NO_2$) reduction or increment.

**Aim and Objectives:**
The aim of this study is for theinvestigation of greenhouse gases reduction rate of Blended Diesel oil using jatropha curcas seed oil in Diesel Engine in Imo State, Nigeria. Toachieve this aim; the following objectives were pursued to:

1. Extraction of oil from Jatropha Curcas seed and production of biodiesel oil from it.
2. To determine the amount of $CO_2$, $SO_2$ and $NO_2$ emitted from a diesel engine powered with the conventional diesel (AGO) and Jatropha curcas seed oil blend biodiesel
3. To estimate the amount of $CO_2$, $SO_2$ and $NO_2$ reduced from diesel engine powered with Jatropha curcas seed oil blend biodiesel or percentage reduction.

**The Importance of Renewable Energy Sources as Alternative Energy for Nigeria.**
The paper by Oyedepo (2012) titled "Energy and sustainable development in Nigeria: the way forward" examined a set of energy policy interventions, which can make a major contribution to the sustainable economic, environmental and social development of Africa's most populated country, Nigeria. Findings revealed that Energy efficiency leads to important social benefits, such as reducing the energy bills for poor households. From an economic point of view, implementing the country's renewable energy target will have significant costs, but these can partly be offset by selling carbon credits according to the rules of the "Clean development mechanism" agreed some 10 years ago, which will result in indirect health benefits. The result of the study also indicated that Nigeria could benefit from the targeted interventions that would reduce the local air pollution and help the country to tackle greenhouse gas emissions. The researcher recommended that government should include full exploitation and promotion of renewable energy resources, energy efficiency practices, as well as the application of energy conservation measures.

Peter (2012) discussed the way to reduce the use of food crops for biofuels by shifting to dedicated energy crops and agricultural residues in the United States using biomass conversion method on our current dependence on fossil fuels which is on a collision course with the need of future generations for a habitable environment. Supplying more than 80 percent of human energy consumption globally, fossil fuel combustion contributes to the rise of atmospheric greenhouse such as $Co_2$, nitrous oxides and methane, which are widely believed to cause detrimental climate change. Findings revealed that we can mitigate these effects by using the many available no or low-carbon methods to harvest energy, including wind, geothermal, hydroelectric, and solar approaches

Pandey, Singh, Kumar, Singh and Singh (2012) carried out a study on *Jatropha Curcas*: A potential biofuel plant for sustainable environmental development in Indonesia were reviewed reports were used in discussing *Jatropha Curcas* L. (JCL) as Unique and potential tropical plant for augmenting renewable energy sources due to its several merits for which it deserves to be considered as sole candidate in the tangible and intangible benefits of ecology and environment. They noted that the species has been advocated for extensive plantations on degraded wasteland throughout the world. But our current knowledge of JCL is inadequate to understand their contribution in societal and environmental benefit on review reports on various roles of *Jartropha Curcas* (JCL) such as effective phyto-remediator, carbon sequester, degraded land development and soil erosion controller were discussed. Findings revealed that this species has received much attention because of its immense role in bio-diesel production an eco-friendly fuel, bio-degradable, renewable ad non-toxic in nature compared to petro-diesel except few carcinogenic compounds found in oil cake. The Researcher recommended further exploitation on its application, extension, risks and beneficial role in tropical environment so that its further scope to mitigate energy crisis, environmental management and sustainable productions could be ascertained.

## MATERIALS AND METHODS

This section will detail the research design adopted, the data need, types and sources of data, target population, sample size and samples techniques, instruments of data collection and method of data analysis and presentation.

Considering the aim and objectives of this study, experimental research design was applied. This involved the procedural production of biodiesel from harvested *Jatropha Curcas* seed and its refining. The volume of JCS oil that was be recovered from a known quantity of JCS seed; the rate of $CO_{2,}$ $S0_2$ and$N0_2$ emissions powered with conventional diesel and when powered with blended diesel were all gotten from the laboratory experiment conducted.

Considering the samples collected for the Jatropha Curcas seed oil extraction, the Jatropha seed farm at Obowo becomes the target from which the sample was drawn. The target population here is the 500 hundred hectares *Jatropha Curcas* Seed plantation in Umunachi, Obowo. From this population of *Jatropha Curcas* plants that are ripe was selected and the seeds was collected as samples for the laboratory experiment. The sampling of the Jatropha Curcas farm, the sample size determined by the researcher using his discretion as samples was collected from the area of the farm which the owner has given the researcher access to. But going by the proposition of Smith (2013), for massive exposures the researcher took one fifth of the whole land mass sampled. Hence the researcher covered about 100 hectares of the farm land which is about 20% of the whole population in order to get the quantity of ripe *Jatropha Curcas* seed that may be needed for the experiment. The Judgemental or Purposive Sampling technique was adopted. This non-probability sampling method is necessitated by the fact that there is no systematic method that will be applicable as the farm is of known geology, the researcher therefore picked and harvested any plant that was matured or ripe, leaving-out the ones that are not matured or unripe. This sample collection continues until the quantity needed is realized, about two bags of the seeds which were estimated to be between 70 to 100 Kilogrammes.

**Instruments for Data Collection**: The instrument for data collection in experimental design is the laboratory experiment. It comprises mostly of laboratory instruments and reagents which the researcher used in exploring the materials available to obtain the data need.

**Biodiesel Production:** For biodiesel to be produced, the oil was first extracted from the vegetable. Followedby thetrans-esterification process and finally,separation of the biodiesel from the glycerol.

**Trans-Esterification Procedure**: The bench scale trans-esterification reactions to produce methyl esters from Jatropha oil were carried out in a 1-liter conical flask (here after referred to as the reactor) equipped with a thermometer and mounted on a magnetic. Stirrer hot plat (Stuart Scientific).

The magnetic stirrer was set at a constant speed throughout the experiment to ensure uniform agitation. 400ml of the extracted oil was poured into the reactor and heated to $45^{0c}$to improve the oil's mix-ability with methanol. The catalyst used was potassium hydroxide (KoH) Pellet, analytical grade (Biolab, Uk) and was prepared in concentration range of 0.5%w/v have to 1.2%w/v, increments of 0.1%w/v.

**Separation of the Glycerol and Biodiesel:** At the end of the 1-hour reaction time, the mixture was poured into a separating container and allowed to fall under gravity. There was an instant distinct separation of the methyl ester and glycerol. It was however be allowed to stand over-night for proper separation. The upper layer in the separating container is most times lighter yellow in colour is biodiesel while the bottom layer which most times is brown is the glycerol and it is a denser liquid.

**Collection of the Biodiesel:** A beaker was placed under the separating container and the glycerol was drained-off leaving the biodiesel. Then another beaker was placed under the separating container to collect the biodiesel. The measurements of both the glycerol and the biodiesel was taken.

## PRESENTATION OF RESULTS

The results of the laboratory analyses were summarized and presented in the following table 1 and 2.
To determine the amount of $CO_2$, $SO_2$ and $NO_2$ emitted from a diesel engine poweredwith the conventional diesel (AGO) and Jatropha curcas seed oil blend biodiesel

**Table 1: Amounts of Gases Emitted for Biodiesel Blends at Variable speeds**

| S/No | Diesel blend | 1000rpm | 1300rpm | 1600rpm |
|---|---|---|---|---|
| $CO_2$ | | | | |
| 1 | **B0 = Diesel** | 380 | 408 | 446 |
| 2 | **B100 = JSOB** | 426 | 442 | 468 |
| 3 | **B20** | 364 | 382 | 402 |
| 4 | **B40** | 328 | 342 | 368 |
| 5 | **B50** | 602 | 628 | 632 |
| $NO_2$ | | | | |
| 1 | **B0 = Diesel** | 13 | 14 | 15 |
| 2 | **B100 = JSOB** | 14 | 15 | 17 |
| 3 | **B20** | 13 | 15 | 16 |
| 4 | **B40** | 15 | 17 | 19 |
| 5 | **B50** | 16 | 18 | 20 |
| $SO_2$ | | | | |
| 1 | **B0 = Diesel** | ND | ND | ND |
| 2 | **B100 = JSOB** | 8 | 10 | 12 |
| 3 | **B20** | ND | ND | ND |
| 4 | **B40** | ND | ND | ND |
| 5 | **B50** | 2 | 3 | 4 |

**Source:** Researcher's Field Survey, 2023

Table 1 has gas emission test for biodiesel blend at variable speed. The table has the amount of $CO_2$, $SO_2$ and $NO_2$ emitted from a diesel engine poweredwith the conventional diesel (AGO) and Jatropha curcas seed oil blend biodiesel.

It can be seen that with the conventional diesel (AGO), that is B0), the $CO_2$ emissions are 380 ppm, 408 ppm and 446 ppm at 1000 rpm, 1300 rpm and 1600 rpm respectively. At B100 = JSOB, that is 100% JSOB, the amount of $CO_2$ emitted are 426 ppm, 442 ppm and 468 ppm at 1000 rpm, 1300 rpm and 1600 rpm respectively. At the blend of B20 (20% JSOB: 80% Diesel), the emissions of $CO_2$ at 100rpm, 1300 rpm and 1600 rpm are respectively 364 ppm, 382 ppm and 402 ppm. Using 40% JSOB: 60% Diesel (that is B40), the emissions of $CO_2$ at 1000rpm, 1300rpm and 1600rpm are 328ppm, 342ppm and 368ppmrespectively. Finally, when the blend was at 50% JSOB: 50% Diesel, that is B50, $CO_2$ emissions were 602ppm at 1000rpm, 628ppm at 1300rpm and 632ppm at 1600rpm.

The emissions of $NO_2$ as seen in the table with the conventional diesel are 13ppm, 14ppm and 15ppm respectively at 1000rpm, 1300rpm and 1600rpm. Using B100=JSOB (100% JSOB), the amounts of $NO_2$ emitted were recorded to be 14ppm, 15ppm and 17ppm at 1000rpm, 1300rpm and 1600rpm respectively. At 20% JSOB: 80% diesel (B20), amounts of $NO_2$ emitted were 13ppm, 15ppm and 16ppm respectively at 1000rpm, 1300rpm and 1600rpm. When the blend was 40% JSOB and 60% diesel, the amounts of $NO_2$ emitted were 15ppm, 17ppm and 19ppm respectively at 1000rpm, 1300rpm and 1600rpm. Finally, at 50% JSOB and 50% diesel, the $NO_2$ amounts emitted are 16ppm, 18ppm and 20ppm at 1000rpm, 1300rpm and 1600rpm respectively.

From the table, when conventional diesel (AGO) was use, $SO_2$ was not detected at 1000rpm, 1300rpm and 1600rpm variable speeds, while at 100% JSOB, it was detected to be 8ppm, 10ppm and 12ppm respectively at the same variable speeds. $SO_2$ was not detected at 20% blend of JSOB and 80% blend of diesel as well as at 40% JSOB and 60% diesel blend, at the three variable speeds of 1000rpm, 1300rpm and 1600rpm respectively. At blend of 50% JSOB and 50% diesel, the amounts of $SO_2$ emitted are 2ppm, 3ppm and 4ppm respectively.
To ascertain the amount of $CO_2$, $SO_2$ and $NO_2$ reduced from diesel engine powered with Jatropha curcas seed oil blind biodiesel or percentage reduction.

**Table 2: Percentage reductions of $CO_2$, $SO_2$ and $NO_2$**

| S/No | Diesel Blend | 1000rpm | | | 1300rpm | | | 1600rpm | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Emitted | Diff. | % | Emitted | Diff. | % | Emitted | Diff. | % |
| $CO_2$ | | | | | | | | | | |
| 1 | **B0** | 380 | Nil | Nil | 408 | Nil | Nil | 446 | Nil | Nil |
| 2 | **B100** | 426 | –46 | –12.1 | 442 | –34 | –8.3 | 468 | –22 | –4.9 |
| 3 | **B20** | 364 | 16 | 4.2 | 382 | 26 | 6.4 | 402 | 44 | 9.9 |
| 4 | **B40** | 328 | 52 | 13.7 | 342 | 66 | 16.2 | 368 | 78 | 17.5 |
| 5 | **B50** | 602 | –222 | –58.4 | 628 | –220 | 53.9 | 632 | –186 | 41.7 |
| $NO_2$ | | | | | | | | | | |
| 1 | **B0** | 13 | Nil | Nil | 14 | Nil | Nil | 15 | Nil | Nil |
| 2 | **B100** | 14 | –1 | –7.7 | 15 | –1 | –7.1 | 17 | –2 | –13.3 |
| 3 | **B20** | 13 | 0 | 0.0 | 15 | –1 | –7.1 | 16 | –1 | –6.7 |
| 4 | **B40** | 15 | –2 | –15.4 | 17 | –3 | –21.4 | 19 | –3 | –20 |
| 5 | **B50** | 16 | –3 | –23.1 | 18 | –4 | –28.6 | 20 | –5 | –33.3 |
| $SO_2$ | | | | | | | | | | |
| 1 | **B0** | ND | Nil | Nil | ND | Nil | Nil | ND | Nil | Nil |
| 2 | **B100** | 8 | Nil | Nil | 10 | Nil | Nil | 12 | Nil | Nil |
| 3 | **B20** | ND | Nil | Nil | ND | Nil | Nil | ND | Nil | Nil |
| 4 | **B40** | ND | Nil | Nil | ND | Nil | Nil | ND | Nil | Nil |
| 5 | **B50** | 2 | Nil | Nil | 3 | Nil | Nil | 4 | Nil | Nil |

**Source:** Researcher's Field Survey, 2023
***Key to table 2***
**D = Difference = B0 – B***
**B* = B100, B20, B40 or B50**
Negative value of D implies that B* (B100, B20, B40 or B50) is greater than B0, which in turn means that $CO_2$, $SO_2$ and $NO_2$ were not reduced from diesel engine powered with Jatropha curcas seed oil blend. Positive value means otherwise, that $CO_2$, $SO_2$ and $NO_2$ were reduced from diesel engine powered with Jatropha curcas seed oil blend.

From table 2, the following deductions can be made based on the differences between the amounts of conventional diesel and JSOB at variable speeds.

$CO_2$ emissions when powered with JSOB 100% show that the emission increased by 46ppm, at 1000rpm, representing about 12.1 percent of the amount emitted using conventional diesel. It further follows at 1300rpm and 1600rpm, the emissions did increase by 34ppm (8.3 percent) and 22ppm (4.9 percent) respectively. Using JSOB at 20%, the $CO_2$ emissions were reduced as follows: 16ppm (4.2 percent), 26ppm (6.4 percent) and 44ppm (9.9 percent) at 1000rpm, 1300rpm and 1600rpm respectively. JSOB at 40% recorded decrease in the $CO_2$ emissions resulting in 52ppm (13.7 percent), 66ppm (16.2 percent) and 78ppm (17.5 percent) reductions at 1000rpm, 1300rpm and 1600rpm respectively. Finally, JSOB of 50% increased the CO2 emissions at the three different variable speeds (1000rpm, 1300rpm and 1600rpm) by 222ppm (58.4 percent), 220ppm (53.9 percent) and 186ppm (41.7 percent) respectively.

The table shows $NO_2$ emissions were not reduced using the various blends of JSOB, rather they were increased at the variable speeds, except at JSOB of 20% at 1000rpm, where there was neither increase nor decrease (difference = 0).JSOB of 100% increased the $NO_2$ emission by 1ppm (7.7 percent), 1ppm (7.1 percent), and 2ppm (13.3 percent) at 1000rpm, 1300rpm and 1600rpm respectively. The blend of JSOB of 20% shows that at 1000rpm, the emission of $NO_2$ was neither reduced nor increased, the difference was observed to be 0ppm, while at 1300rpm and 1600rpm, the emissions increased by 1ppm each (7.1 percent) and (6.7 percent) respectively. JSOB of 40% producedhigher$NO_2$ emissions than the conventional diesel with the increments being 2ppm (15.4 percent), 3ppm (21.4 percent) and 3ppm (20 percent) at 1000rpm, 1300rpm and 160rpm respectively. Looking further at the table, we observe that the BSOJ of 50% produced an increment of 3ppm (23.1 percent) of the conventional diesel, 4ppm (28.6 percent) and 5ppm (33.3 percent) at 1000rpm, 1300rpm and 1600rpm respectively.

The conventional diesel emissions for SO2 were not detected at 1000rpm, 1300rpm and 1600rpm respectively, likewise those of JSOB 20% and JSOB 40%. Therefore, we cannot proceed to compare the emissions of JSOB 100% and JSOB 50%, since there are not conventional diesel emissions detected for the comparison.

**Test of Hypotheses**

**Hypothesis:** The rate of $CO_2$ emission reduction from a diesel engine powered by a Jatropha Curcas oil blend diesel is not significant.

The rate of $CO_2$ emission reduction from a diesel engine powered by Jatropha Curcas oil blend diesel was only significant at a single blend of JSOB (40%) that significantly reduced the CO2 emission from a diesel engine.

**Hypothesis:** The $NO_2$ emission from a diesel engine is not reduced when powered with a Jatropha Curcas oil blend biodiesel.

**Decision and Conclusion:** from the table, it can be observed that mean differences for the comparisons of conventional diesel with 100% JSOB, 20% JSOB, 40% JSOB and 50% JSOB are –1.33, –0.67, –3.00 and –4.00, with corresponding p–values 0.057, 0.184, 0.035 and 0.020 respectively. The implication is that for each blend of JSOB, the average emissions of $NO_2$ at 1000rpm, 1300rpm and 1600rpm increased. The increments are significant at 40% JSOB and 50% JSOB; $p=0.035$ and $p=0.020$ respectively while nonsignificant at 100% and 20%.

In conclusion, JSOB at 100%, 20%, 40% and 50% did not reduce $NO_2$ emissions, rather the emissions were increased. Therefore, JSOB is not recommended for $NO_2$ reduction at these percentages and variable speeds; other percentages and variable speeds can be checked

## CONCLUSION AND RECOMMENDATION

In line with the findings of this research work, the following conclusions were made:
The main aim of the investigation of greenhouse gases reduction rate of blended diesel oil using jatropha curcas seed oil in diesel engine was to present jatropha curcas biodiesel to be combustible to conventional diesel and to show that it can be used without modification in a diesel engine to find out whether there is increase or reduction in greenhouse gases concentrations in the atmosphere, jatropha curcas blend biodiesel $Co_2$ increased significantly at 100% when powered with diesel engine

Which is in line with Boehman ,Valer, Scaronia, and Schobert(2004) that says fossil fuel utilization is inherently associated greenhouse gas emissions and increase in $NO_2$ emissions. Therefore the rate of $CO_2$ emission reduction cannot be ascertained since it was only a simple blend of 40% that reduced the $CO_2$ emission from a diesel engine. $SO_2$ was not detected, therefore no basis for comparison. $NO_2$ due to its increase in emission is not recommended for greenhouse gases reduction in diesel engine at 100%, 20%, 40% and 50% percentages and speed. $No_2$ reduction during combustion in a diesel engine at other speed and percentages can be investigated. Large scale production of jatropha to implement the bio-fuel policy to promote use of jatropha biodiesel as alternative to conventional diesel fuel should be passed by government to forestall degradation of the environment.

### Recommendations

Based on the research findings and literature considerations, the following recommendations have been put forward:

1. JSOB is not recommended for $NO_2$ reduction at these percentages 100%, 20%, 40% and 50% and variable speeds; other percentages and variable speeds can be checked.
2. In this era of energy crisis and fast degradation of the environment the government must devise an appropriate plan of action to overcome the challenges of the commercial production of jatropha to implement the bio-fuel policy to promote the use of jatropha biodiesel as substitute to mineral diesel fuel.
3. Radical policy change is necessary such as incentivizing oil production and encouraging oil companies to change their direction.
4. Biodiesel is a renewable energy source that appears to be an ideal solution to meet global energy needs,

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