Study of the effect of using soybean oil on air emissions realised from diesel engine performance

ABSTRACT

Fossil fuel contributes 80% of the word's energy needs. Whereas, the emission produced by the emission of fossil fuels contribute to air pollution and global warming. Biodiesel as one promising alternative to fossil fuel for diesel engines has become increasingly important due to environmental consequences of petroleum-fuelled diesel engines and the decreasing petrol resources. The aim of the current study is to investigate the effect of Soyabean oil blended with "Diesel fuel" on the existing engine emissions. In this study, biodiesel was produced by transesterification of soyabean oil with methanol using sodium hydroxide (NaOH) as catalyst which was blended with diesel. The ratio of diesel to soyabean oil that was used were; 80% diesel-20% soyabean oil (B20), 60% diesel-40% soyabean oil (B40), and 100%diesel-0% soyabean oil (B0). The study revealed that soyabean oil can be processed into biodiesel through transesterification. Soyabean biodiesel blends produced lower CO, HC, and CO_2 emission than diesel fuel while emission of NOx from soyabean biodiesel fuel were found higher than NOx emitted from diesel fuel.

Keywords: Biodiesel, Fossil fuel, Soyabean,Catalyst, Transesterification

1. INTRODUCTION

Diesel engine being most efficient engine today plays an important role in transportation, agricultural sector and to meet many other basic humans need. Fossil fuels from petroleum, coal and natural gas play a very important role in the development of industrial growth. As the fossil fuel resources are depleting day by day because of their lavish consumption; hence it is imperative to find an alternative environment friendly fuel. The high rate of emission from diesel engines has been a great source of concern from an environmental point of view, especially oxides of Nitrogen, oxides of Carbon (CO2 and CO), Hydrocarbon (HC), smoke and particulates. Increasing population growth is making the energy demand higher, and this is correlated to the depletion of world oil reserves and emissions problems. This condition also puts pressure on every country to immediately produce and use renewable energy.

However, the fast depletion, non-renewable nature and environmental impact of the fossil fuels have drawn the world attention to the need for search of energy resources to fill these gaps. Among the various options investigated, biodiesel produced from vegetable oil and other sources has been universally recognized as the foremost contender for exhaust emission reduction. Biodiesel has been considered as one of the most versatile alternative fuel options for petroleum diesel in direct injection diesel engine applications. Biodiesel including alternative fuels is promising because it is renewable, biodegradable, non-toxic and environmentally friendly. The use of biodiesel fuel is also expected to reduce global warming. The use of alternative energy has becomes one of the breakthroughs that can provide solutions in the future. One of the discoveries is to utilize biodiesel fuel from soyabean oil.

Botanically, a mature soyabean seed consists of three basic parts: the seed coat, cotyledons, and germ, or hypocotyls. The seed coat, also called hull, holds two cotyledons together. The cotyledons are known as embryos, which function as food reserve structures. Soyabeans have high amount of protein and oil, and they are used into diverse food products, including soya curd and fermented soya cakes (tofu and tempeh), soya sauce, soya paste (miso), and soya milk. Such hydrolyzed protein is a meat substitute used for many people. Flour made from soyabeans is utilized in processed foods, as a stabilizer and to increase protein content. Soyabean oil is used in cooking, such as margarine, shortening, salad oil as well as in industrial products (paints, printing inks, disinfectants, biofuel, and linoleum). The soyabean derivatives that remains after oil extraction is used to produce fiber, textiles, adhesives, and livestock feed (Ecocrop, 2012, Wyk, 2005).

Soyabean is one of the leguminous crops that are the essential ingredients of many far east foods such as soy sauce and tofu. Currently, soyabean is the most cultivated oilseed crop in the world with most producers concentrated in Americas and Asia regions (Fargione*et al.*, 2008). The soybean oil concerning oil content and fatty acid composition are influenced by varieties and climatic conditions of the growing site. Soyabean oil has a saturated fatty acid content of about 15%, so it is very good as a substitute for fats and oils that have high levels of saturated fatty acids such as butter and animal fat. This means soyabean oil is the same as other vegetable oils that are free of cholesterol. The level of soyabean oil is relatively lower compared with different types of beans, but higher than serelia oil levels. If soyabean oil is to be used in non-food fields, it is not necessary for all purification steps to be carried out.

Soyabean seeds borne on different nodes of the stem and are subjected to positional effects. Oil content and fatty acid composition vary between positions along the axis (Guleria*et al.*, 2007). Soyabean oil and protein are the major economic products obtained from soyabean seed (Fargione*et al.*, 2008). Soyabean oil represents 56% of total oilseed production in the world and is the second most consumed with 27% (Soya, 2014). Seeds in the upper one fourth of the plant contain a higher concentration of protein and lower concentration of oil than that from lower one fourth of the plant. These differences in the oil and protein availability is due to the variations occurring in specific nutrients and assimilates supply and other related factors, probably influencing the germination of the seed (Sharma *et al.*, 2009). The making of soap only needs the process of blanching and deodorization, so that the color and smell of soyabean oil does not pollute the color and fragrance of soap produced. Various processes have been adduced for production of biodiesel, including, micro emulsification with alcohol, catalytic cracking, pyrolysis and transesterification. Specifically, the purpose of this research is to utilize biodiesel from soyabean oil as an alternative fuel for diesel engine and to also determine its influence to exhaust emission.

Yu Zhang*et al.*,(2007) investigated the use of blends of methyl esters of soyabean oil and diesel in a turbo-charged, four- cylinder, direct injection diesel engine modified with bowl in piston and medium swirl type. They found that the blends gave a shorter ignition delay and similar combustion characteristics as diesel. The results of emission concentration in flame show that Total Hydrocarbon (THC) emissions of biodiesel blends are significantly lower than that of conventional diesel. Altin*et al*., (2011) tested single cylinder direct injection diesel engine with the use of methyl esters of sunflower oil, cottonseed oil, soyabean oil and corn oil as fuel. They reported that thermal efficiency did not change and fuel consumption increased compared to diesel. The emissions like CO and HC were reduced by 15% and 16% compared to diesel fuel results. It was also discovered that fueling with biodiesel/diesel fuel blends effectively reduced particulate matter, unburned hydrocarbons, and carbon monoxide while increasing oxides of nitrogen emissions. The optimum blend of biodiesel and diesel fuel, based on the trade-off of PM decrease and NOx increase, was a B-20 fuel blend. Increased NOx emissions can be reduced by retarding engine timing while subsequently maintaining emission reductions associated with fuelling a diesel engine with a B-20 fuel blend. The aim of the current study is to investigate the effect of Soyabean oil on diesel engine emission.

2. MATERIAL AND METHODS

Biodiesel was produced by transesterification of soybean oil with methanol using sodium hydroxide as catalyst which was blended with diesel. The following are the ratio of diesel to soyabean oil that as used; 80% diesel-20% soyabean oil (B20), 60% diesel-40% soyabean oil (B40) and 100% diesel-0% soyabean oil (B0).

Production of Biodiesel

In the production of Biodiesel through the transesterification was carried out at Animal Production and Health (APH) at Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Oyo State. From the existing literature review, 500 ml of refined soyabean oil was preheated to 50-55°C for 1 h to increase reaction capacity of refined soyabean oil with alcohol. Then methanol (100 ml) was taken in beaker and sodium hydroxide (NaOH) (2.5 g) as a base catalyst was added and stirred vigorously for 30 mins. Refined soyabean oil and oxides of sodium and methanol was mixed in a beaker to form esters. Entire mixture was put in a Thermostatic water Bath shaker for 1h at a temperature of 60^oC, After 1hr the mixture was removed and poured into separating funnel and was kept for a day (24 hr) when the glycerol got settled at the bottom of the separating funnel leaving ester at the Top. The entire process was repeated 10 times for the 5000 ml of refined Soyabean oil used.

Biodiesel purification by wet washing

After transesterification, the upper ester layer contained traces of methanol and glycerol. The remaining un-reacted methanol has safety risk as it could corrode the engine parts, and the remaining glycerin in the biodiesel will lessen the fuel lubricity and cause injector coking and other deposits Ogunsuyi, (2015). Such trace of methanol is soluble in water and therefore it was removed by wet washing. The methyl ester or biodiesel layer was gently washed with hot distilled water in the ratio of 3:1 water to methyl ester. The methyl ester was gently washed to prevent its loss due to formation of emulsion that will result when phase separation is completed (Umeuzuegbu 2019). The washed biodiesel was dried by heating at 105^oC on a laboratory hot plate until all residual water molecules evaporated. Figure 1 shows the processes involved in transesterification of Soyabean oil.

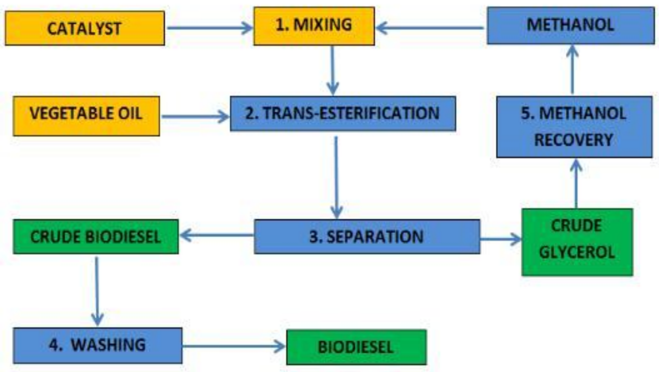

Fig 1: Soyabean oil transeterification process

Determination of the fuel properties of used soya oil biodiesel produced

The properties of the biodiesel fuel were characterized based on ASTM standards. The biodiesel properties characterized include density, viscosity, and flash point.

Flash Point

Flash point is the lowest temperature at which liquid can form an ignitable mixture in air near the surface of the liquid. The lower the flash point, the easier it is to ignite the material. The flash point of the test fuel should be within minimum of 130^{o}C.This was done by heating the biodiesel in a container and the small flame was introduced above the surface of the biodiesel while record will be taken by thermometer. The temperature at which there is an ignition was recorded as flash point.

Density

Measuring the density involve weighing the biodiesel on weighing balance and measure the same by volume (measuring cylinder). Density of the biodiesel was determined as

$$Density = \frac{Mass\ (kg)}{volume\ (cm^3)} \quad (1)$$

Where the weight is measured in g and volume measured in cm^3

Viscosity

Viscosity is the mechanical friction between molecules in motion and resistance to deformation because of mutual attraction of the molecules, in other word, it is resistance to flow.Capillary viscometer will be used to measure the viscosity of the biodiesel. This will be done by passing the biodiesel through the length of the tube, while the stopwatch recording the time to complete the passage. As required by American Society for Testing and Materials ASTM 445 (1.9 – 6.0), viscosity experiment will be carried out at 40^{o}C

$$Viscosity = \frac{length\ of\ the\ tube\ (mm)}{Time\ taken\ (sec)} \quad (2)$$

Engine performance evaluation test

The engine performance evaluation test of the biodiesel was carried out on a R175A lister diesel engine. The engine is a single cylinder, water-cooled, naturally aspirated, 4-stroke CI engine. The engine specification is given in Table 1. The experiment was conducted with diesel fuel, biodiesel and the blends are, 80% diesel-20% soyabean oil (B20), 60% diesel-40%

soyabean oil (B40), 100%diesel-0% soyabean oil (B0). A short test run was `done in order to ensure that all essential accessories were in working order before the actual test.

Table 1: The R175A Diesel Engine Specifications

Model	R175A
Type	Single-cylinder Horizontal Four-stroke
Combustion system	Pre-combustion chamber
Bore x stroke (mm)	75 x 80
Compression ratio	22 ± 1
1-hour rated output (kW/r/min)	4.85/2600
12-hour rated output (kW/r/min)	4.41/2600
Specific fuel comsumptioning/kw h	≤ 277.4
Specific lube oil consumptioning/kw h	≤ 4.76
Cooling system	Hopper Warter-cooled
Lubrication system	Combined pressure and Splashing
Starting method	Hand crack
Net weight (kg)	65
Method of power output	Output of flywheel end
Overall dimensions (mm)	589 x 341.5 x 463

Source: Impact of used soya oil biodiesel on the performance and emission of diesel engine (2020)

Engine emission test at constant speed (varying load)

Emission test was carried out at Mechanical Engineering Laboratory of Ahmodu Bello University, Zaria, Kaduna State. The experiment was performed at an engine speed of 1300rpm and 1600rpm. The exhaust gases, NO_2, CO_2, CO, and HC were measured with a portable digital gas analyzer (NHA-506EN automotive emission analyzer). The data of exhaust emissions were taken from the probe of the gas analyzer. After taking the necessary readings at this specified speed, the load on the engine was varied using the dynamometer loading wheel. The procedure was repeated for higher loads 40kg, 60kg, 80kg and 100kg. A type K thermocouple was used to measure the gas temperature at a different position in the experiment setup. Filter based smoke meter was used to measure the level of smoke emission. All the experiments were performed at ambient temperature of 25^{o}C (± 2^{o}C). In this study, diesel engine fueled with different blends of soyabean oil was experimentally used.

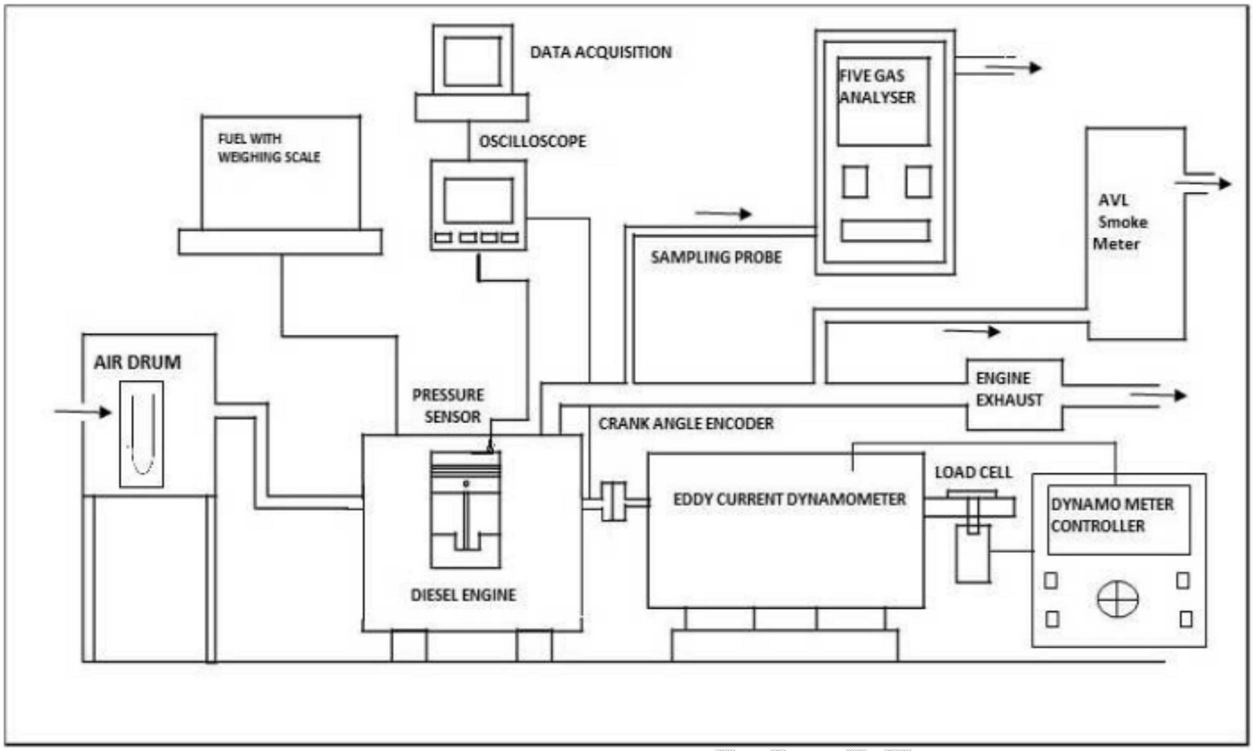

Fig. 2: Line diagram of experimental set-up
Source: Shaik*et al.*, (2019)

3. RESULTS AND DISCUSSION

Quantitative analysis for Soyabean oil

The total of 5000ml quantity of Soyabean oil was used; however, the total purified palm oil obtained by combining with Sodium hydroxide (NaOH) after saponification reaction was 4650 ml.

Physicochemical properties of Biodiesel

The test analyzer used in the elemental analysis is usually employed for the determination of carbon and hydrogen content of liquid fuels including gasoline, diesel, biodiesel blends, and gasoline-ethanol blends. Table 2 shows the physiochemical properties of fuel blends used for the study.

Table 2: Physiochemical properties of Diesel fuel and various blends of biodiesel

Property	Diesel B0	B20	B40
Density at 15^{o}C (kg/^{3})	830	842	852
Viscosity at 40^{o}C (cSt)	6.5	7.6	8.4
Flash Point (^{o}C)	66	84	89
Calorific Value (MJ/kg)	44	43.95	43.75

Emulsification Test

Equal volume (500ml each) of biodiesel and water were mixed and shake together in the separating funnel. The used cooking oil biodiesel separating fast and the biodiesels layer appear clearly above the water phase. Both biodiesels and the water appear clearly at their respective phase. This suggests the true formation of the biodiesel.

Emission Characteristics

The important emission characteristics of diesel engine include smoke, oxides of nitrogen, carbon monoxide and unburned hydro carbon emissions. These emissions emitted by the engine when fueled with biodiesel blends, (B20 and B40) have been compared with diesel and reported in figure 2 and 3. The variation of engine speed with respect to engine power at full load is presented in figure 2 and 3; the CO, CO_2, HC and NO emissions of Soyabean oil biodiesel blends (B20 and B40) are compared with diesel under 2 different engine speeds.

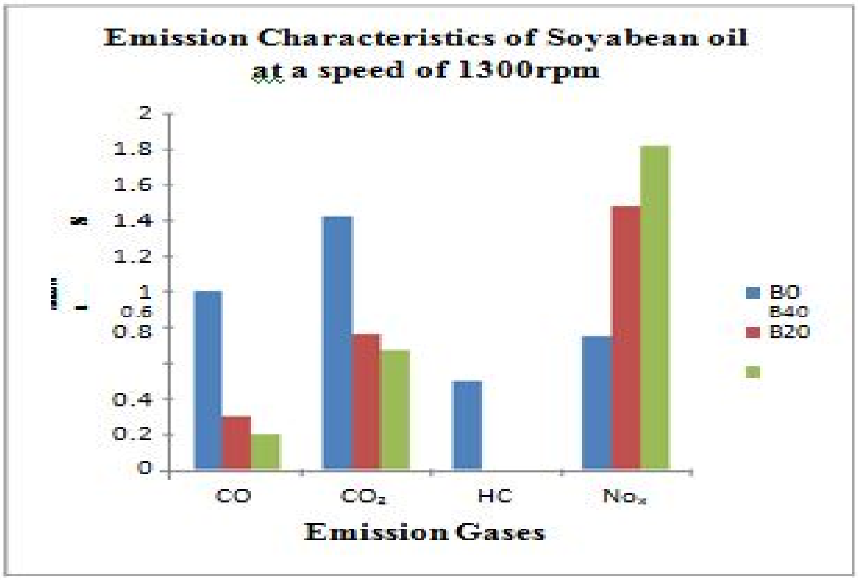

Fig. 2: Emission Characteristics of Soyabean oil at a speed of 1300rpm

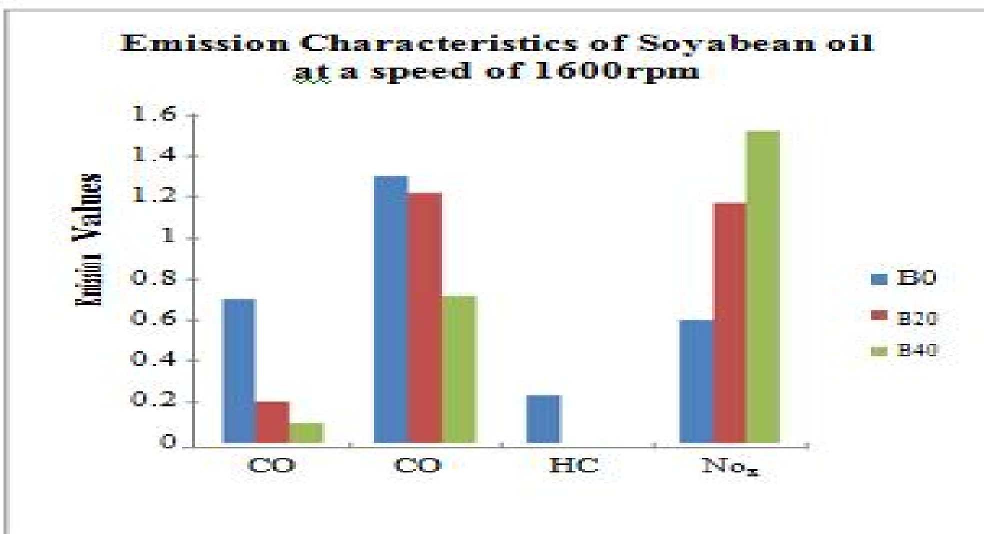

Fig. 3: Emission Characteristics of Soyabean oil at a speed of 1600rpm

i. Carbon Monoxide (CO) Emission

According to biodiesel's emission characteristics, CO emissions in engines happen as a result of incomplete fuel combustion. Low air-to-fuel ratio is the primary cause of this problem, which is also known as incomplete combustion. CO can, however, form for a variety of reasons, including fuel qualities; spray characteristics, engine load, low temperature, and insufficient time for conversion (Behçet, 2011). Engine performance is negatively impacted by the CO, which represent wasted chemical energy losses. Variations in the CO emissions of the biodiesel test fuel (soybean oil) were shown in figure 2 and 3at various engine speeds. At engine speeds of 1300 rpm and 1600 rpm, soyabean oil biodiesel fuels produced less carbon monoxide (CO) emissions than diesel fuel. The CO emission values for biodiesel fuels drop as the blend ratio rises. Additionally, the amount of CO in the fuel is highest at low engine speeds of 1300 rpm and reduces when the speed is 1600 rpm. Thus, CO decreases as fuel's biodiesel content rises, demonstrating that using biodiesel led to fewer carbon monoxide (CO) emissions. This might be explained by biodiesel's high oxygen concentration and lower carbon to hydrogen ratio.

ii Hydrocarbon (HC) Emission

Unburned HC (hydrocarbon) is one of the exhaust pollutants from internal combustion engines that results from incomplete combustion. Because the temperature cannot reach ignition point or there is a lack of oxygen in the surroundings, the fuel is either partially or not at all oxidized, which results in the presence of unburned hydrocarbons in combustion products. Regions with incomplete combustion produce HC emissions. Engine load and speed have no direct impact on HC emissions. Instead, it depends on how the combustion chamber and injection mechanism are shaped. The amount of emissions is influenced by the kind and geometry of the combustion chamber. Unburned HC emissions are decreased as a result of increased air movements (turbulence) caused by an increase in revolution (Ozsenen *et al.*, 2008). The emissions of unburned HC are displayed in figure 2 and 3with respect to 1300 rpm and 1600 rpm. The figure shows that the unburned HC emissions from the combustion of blend fuels (soybean oil of B20 and B40) were lower than those from the combustion of diesel fuel.

iii. Nitrogen Oxide Emission

Figure 1 and 2 illustrates how NOx levels change as a function of engine speed while using soybean oil biodiesel fuels, and diesel fuel. Thefigures demonstrates that for all engine speeds, the NOx emissions from an engine running on biodiesel fuel (B20 and B40) were higher than those from an engine running on diesel fuel. A significant percentage increase in NOx emission was observed at 1600 rpm. The generation of NOx is known to be significantly influenced by temperature and oxygen content, according to (IIklic 2009). The amount of NO that is produced increases with temperature and residence time at high temperatures in the cylinder. Murillo *et al.*, (2007), Hazar (2009), Ozsenen *et al.*, (2009) and Karabectas (2009) in their findings reported that the use of biodiesel increases the emission of NOx.

iv. Carbon (IV) Oxide (CO2) Emission

The combustion of diesel fuel ideally would produce carbon (iv) oxide (CO_2) and water (H2O) only. The carbon from the fuel combines with oxygen to produce carbon (iv) oxide (CO_2). CO_2 is the main cause of concern in the World at the moment, and one of the main subjects of international agreements is to reduce its emissions. It is causing global warming. It is produced by any burning of fossil fuels and biofuels. The combustion of biofuels also produces CO_2, but crops are readily absorbing it, hence CO_2 levels are kept in balance. It is very important to observe that, in a global balance, these fuels can limit strongly the rise of CO_2 in the atmosphere because of their vegetal origin (Behçet, 2011). Figure 2 and 3 demonstrates that for the engine speeds used, the CO_2 emissions from an engine running on biodiesel fuel (B20 and B40) were lower than those from an engine running on diesel fuel.

CONCLUSION

Air pollution is something that we cannot really ignore nowadays. This is evident from the moment we step out of our house and are greeted with black colored smoke that hit us directly. This smog is not due to climate but rather due to each and every one of us.

Based on the findings of the study the following conclusions were drawn out:

i. The study revealed that soyabean oil can be processed into biodiesel through trans-esterification.
ii. The densities value of fuel produced from soyabean oil was found higher than diesel; On the other hand, diesel fuel possessed higher calorific value than soyabean oil biodiesel.
iii. The use of mixture of diesel and soyabean oil didn't cause any changes in the rounds of the engine, in the consumption, as well as in the supply of water. On the other hand it constituted changes to CO, HC, NO and CO2.

iv. CO emissions are reduced when the fuel temperature and the percentage of soyabean oil in diesel are increased. CO_2 emissions are reduced when the percentage of soyabean oil in diesel are increased. The NOx emissions are influenced by the fuel temperature and the percentage of soyabean oil in diesel.

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