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Diesel Engine Emission And Performance Characteristics Fuelled With Jatropha Biodiesel. A Review

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Abstract.- *The increase in demand for fossil fuel resources and environmental degradation has led researchers to seek a suitable substitute for fuels that are renewable and environmentally friendly. Biodiesel is one of the alternative fuels that received more attention as a substitute for diesel fuel. Its ability to reduce carbon monoxide, HC and particulate matter makes it an outstanding alternate fuel. The main purpose of this paper is to review the performance, combustion, and emission characteristics of biodiesel derived from non-edible Jatropha oil. Jatropha biodiesel (JB) has been found to possess properties that are within the acceptable range as stipulated by the ASTM. The review focused on three engine performance parameters: Brake power (BP), Brake specific fuel consumption (BSFC), and Brake thermal efficiency (BTE). From the review, the diesel engine can run smoothly with Jatropha biodiesel. The observations from several researchers showed a decrease in BP, BTE, and an increase in BSFC in comparison with diesel fuel. Emission parameters like Carbon monoxide (CO), Carbon dioxide (CO2), Hydrocarbons (HC), Nitrogen Oxides (NOx), and Particulate matter (PM) were observed during the test. CO, CO2, HC, and Particulate matter were found to be lower than that of diesel fuel. However, a significant increase in NOx emission was spotted. Lower cylinder pressure, together with heat released, was evident when using Jatropha and its blends (JB20, JB40, JB80, and JB100). JB20 proved to be the best blends as it yielded improved and acceptable results in performance and emission as compared to 100% Jatropha biodiesel. In view of the findings of the review, it can be concluded that Jatropha biodiesel can be the alternate fuel in the near future.*

Keywords - *Jatropha, Biodiesel, diesel engine*

I. Introduction

The dependence of humanity on energy has grown over the years and has almost reached a point of extinction. In today's world, human consumption of energy has increased due to economic growth and population growth. Sources of energy used today mostly come from fossil fuels. Despite their outstanding advantages, these fuels are becoming limited and are harmful to the environment [1].

For several years, diesel engines have been considerably used in mechanical engines, power generators, construction equipment, mobile drives, and industrial applications [2]. Diesel burns slowly and has a higher compression ratio which makes it possible to generate greater torque that gives the vehicle ability to pull heavier loads and still have good acceleration rates. The longer carbon chain in diesel results in higher energy density in comparison with that gasoline [3].

Recently, diesel fuel has received much recognition in internal combustion engines. The composition of diesel engine exhausts consists of numerous gases and particulate pollutants. These gaseous emissions are Nitrogen oxide (NO_x), hydrocarbons (HC), Carbon monoxide (CO), Nitrogen dioxide (NO_2), and Nitric oxide (NO) [4]. However, these engine exhausts emissions have proved to be harmful to humans and the environment. [5]. PM, NOx, CO, and HC have been associated with sicknesses like Asthma, Cancer, and asphyxiation. The emission of NOx and HC leads to ozone formation and the greenhouse effect [6].

However, this rapid depletion, environmental concerns, and high demand for fossil fuels have led researchers to shift their focus towards finding environmentally friendly and cost-effective alternative fuels which can replace fossil fuels [7]. Though Modifications of engines, oxidation catalyst, and EGR methods have been tried, reduction of NOx and PM simultaneously is still challenging. The shift has already singled renewable resources as alternate fuels as they are environmentally friendly and cost-effective.

Enweremadu and Rutto (2010) [8] states that researchers have identified vegetable oil that has properties (cetane number, viscosity) and performance characteristics that resemble that of diesel. However, this oil needs to go through a process (pyrolysis, transesterification, dilution, and microemulsion) and be converted to biodiesel.

Biodiesel is a clean and renewable fuel that contains monoalkyl esters of fatty acids [7]. Enweremadu and Rutto (2010) [8] further states that biodiesel is more advantageous as it reduces carbon dioxide emissions and it is safer to handle. Animal fats and edible or non-edible vegetable oils maybe use as sources of biodiesel oil. Murugesan *et al.* (2009) [2] states that Rudolf Diesel used vegetable oil as an alternative fuel to run his diesel engine.

However, the sustainability of biodiesel production is dependent on the oil yields of the crops. The more oil the crops yield, the lesser it shall be to produce biodiesel.

When a diesel engine was manufactured, it was not meant to run with biodiesel. Researchers have written several papers to compare the performance, combustion, and emission characteristics when an engine is run with biodiesel and petroleum-based diesel.

Therefore, the objective of this paper is to analyze the performance, emission, and combustion characteristics of diesel engines run on Jatropha biodiesel and petroleum-based diesel using a review of kinds of literature. Jatropha oil is non-edible. Gui, M et al. (2008) [9] has proved that among the non-edible oil, Jatropha yields more oil per hectare.

A. Diesel engine

A German-born engineer named Rudolf Diesel noticed the waste which was associated with a steam engine. Diesel noted the air pollution by smoke from the boiler furnaces and energy loss from the steam engine. This led Diesel to design an engine that may utilize the energy from coal without steam as an intermediate medium.

The initial stage of Diesel's invention began in 1890 – 1893, a compression ignition engine idea is conceived. The idea is to develop an engine that may allow combustion to take place isothermally. Its piston will daw in the air on a downstroke and compresses to high temperature and pressure. The second downstroke allows fuel to flow in, which will result in an expansion process. The engine did not run, but Diesel picked up that the pressure was too low.

In 1894 – 1897 Diesel worked on getting high pressure, fuel type, injection, and ignition. Diesel thought that any fuel might ignite when in contact with hot air, but the opposite was the case and finally settled for paraffin as fuel [10].

The principle of operation of a diesel engine is like that of a gasoline engine which uses the heat energy released by combustion to converts fuel energy into mechanical energy. For normal combustion in this engine, excessive air is required. In the beginning, these engines were used in ships and submarines. In the mid-19th century, the diesel engine was introduced in the automobile industry, and its use grew to a point where it is mostly preferred in the 21st century than gasoline [11]. According to Kannan and Udayakumar ([12], Reliability, fuel efficiency, and durability make this engine the most preferred.

B. Alternative fuels

When Rudolf developed the combustion engine, his intention was to use gasoline as fuel. To his surprise, it turns out that gasoline was resistant to auto-ignition. This made gasoline fall into the list of unsuitable fuels. As several tests where being conducted, kerosene turns out to be the suitable fuel for the engine. As time passes, it was revealed that diesel fuel, a by-product of gasoline, is a suitable fuel for the engine. Though it had technical challenges, its better efficiency and cost-effectiveness made it a better option. With time this diesel fuel has been refined, and currently, in South Africa, there are two types of diesel, i.e., Standard grade diesel and Low sulphur grade diesel.

Table 1: Properties of Diesel Fuel [13]

Properties	
Density (kg/m^3)	835
Viscosity (mm/S^2)	2.72
Cetane number	52
Flash point °C	>55
Solubility	Immiscible
Self-ignition temperature °C	254 – 300
CFPP °C	-17
Lubricity	315
Boiling point °C	180 – 360

a) Alcohol

Alcohol-based fuels have gained a huge favor over the entire world to be used as a substitute for diesel fuels. This is because it contains high oxygen, which in turn improves combustion effectively. Alcohols are liquid biofuels that come from the biological fermentation of biomass. They have been used widely in CI engines because of their economic benefits and their compatibility with the diesel engine. These alcohols may be classified as lower alcohols (short-chained alcohols) and higher alcohols long-chained alcohols). The fermentation process is employed in alcohol production as it is environmentally friendly and cost [14].

1) Lower Alcohols

Lower alcohols are alcohols that contain less carbon atoms, i.e., Methanol – 1 carbon atom, Ethanol – 2 carbon atoms, and Propanol – 3 carbon atoms. Lower alcohols have been favored the most as they are affordable, and the reduction of emissions is high.

Several tests have been conducted on using lower alcohols as a replacement for diesel fuel in CI engines. However, the tests proved that lower alcohols have several downsides like poor lubricating properties, poor miscibility when blended with conventional diesel, increase CO and HC emissions, low cetane number, low flashpoint, and poor engine performance. These downsides prevent the use of lower alcohol in CI diesel engines [15].

2) Higher Alcohols

Higher alcohols are those alcohols that contain 4 or more carbon atoms, i.e., Butanol, Pentanol, dodecanol, hexanol, octanol, and phytol. Butanol – 4 carbon atoms, pentanol – 5 carbon atoms, Hexanol – 6 carbon atoms, Octanol – 8 carbon atoms, Dodenol – 12 carbon atoms, and Phytol with 20 carbon atoms. Studies have proven that higher alcohol can also be used with conventional diesel without phase separation [16].

Higher alcohols improve the properties of diesel fuel such as density, viscosity, better blend stability, high cetane number, and flashpoint, which results in improved handling [6]. Rajesh Kumar and Saravanan (2016) [16] have studied higher alcohols and found that they are less hygroscopic. This property makes higher alcohols favorable as they are less corrosive.

C. Biodiesel

Biodiesel is a clean, natural fuel that comes from renewable sources and may be used in a diesel engine with or without any engine modification [17]. Several researchers have proved that biodiesel is the most important renewable source of energy. This is due to its ability to attain the energy demand, reduce greenhouse gases and global warming. Cetane number, viscosity, and energy content resemble that of diesel fuel. The outstanding advantages of biodiesel are its biodegradability, ability to blend with diesel, and can be used it with little or without any modification to the engine [18].

In the quest search for alternative fuel, Rudolf Diesel ran his diesel engine using peanut oil as fuel. However, several issues arose; the impact of engine performance and lifespan, fuel preparation methods, the costs of producing this fuel, extraction and production of oil from seeds, and higher viscosity that results in clogging. This issue, however, did not stop the desire to develop alternative fuel but also invokes researchers to find more ways to improve this alternative fuel[19].

II. Biodiesel and its sources

Sources like algae, animal fats, waste oil, and vegetable oils may be used to produce biodiesel. However, it is critically imperative to go through the proper selection of feedstock for biodiesel as it may have an impact on the costs, purity, and composition. Though these raw materials are also contingent on the areas, oil content, properties, composition, and suitability plays a major role in the selection of the right feedstock [19].

Categories of biodiesel feedstock

- Vegetable oil – this can be divided into two groups:
- Edible – Soya beans, Sunflower oil, Peanut, Canola, Palm, Coconut oil
- Non-edible – Jatropha curcas, Moringa, Pongamia Pinnata, Castor oil
- Animal fats – Chicken, Beef, Pork
- Waste oils

A. Edible and Non-edible

Edible oil is oils that can be used as food for human consumption. The production of biodiesel from edible oil has raised lots of concerns as these oils are used as food for humans. The scarcity of food makes it humanly impossible to use these oils for biodiesel production. Furthermore, the production of biodiesel from these oils will be expensive as their prices will also increase due to high demand. The hike in prices will result in an increase in food prices [11].

However, the production of biodiesel from non-edible vegetable oils proves to be substantial. Non-edible oil is not meant for human consumption due to its toxicity or health-threatening effects on humans.

a) Sunflower oil

A 4-cylinder turbo diesel-run using sunflower biodiesel at different speeds showed a decrease in HC and CO emissions. These results were better compared to diesel fuel. Higher oxygen content in biodiesel results in increased combustion quality which in turn results in favorable effects on air quality [9].

b) Soyabean oil

Qi *et al.* [20] ran a direct injection engine fuelled with soybean biodiesel blends, an increase in combustion quality was noted due to higher oxygen content. However, the presence of high oxygen in the chamber results in an increase in NO_x emissions and a slight decrease in CO and HC. BTE of biodiesel records a slight decrease at low loads.

c) Palm oil

Gui et al. [9] studied the performance, combustion, and emission characteristics of a diesel engine fuelled with Palm oil. Though Palm oil yields the highest oil per hectare, high specific fuel consumption was recorded due to low energy content. There was a reduction in NO, HC, and CO.

Though studies prove that edible vegetables yield more oil, the challenge of human nutrition versus fuel makes it economically unfeasible.

B. Jatropha Oil

Jatropha is a euphorbiaceous plant that naturally grows in tropical and subtropical countries, such as China, India, Sub-Saharan Africa, and Southeast Asia. It is a two-worded name that originates from Latin, Jatro – doctor and trophe – food, mainly used for medicinal purposes. Naturally takes 3 – 4 months to become a mature adult plant. Studies state that once this plant matures, it can produce seeds for 50 years. This plant stores approximately 30% - 50% of oil in its seed [21].

The properties of Jatropha oil and that of diesel fuel are similar except for the viscosity. Jatropha oil has a high viscosity, which may result in incomplete fuel combustion, carbon deposits, and reduction of engine life span [22]. Therefore, the reduction of viscosity of Jatropha oil is of great importance to ensure that Jatropha oil remains alternative fuel for diesel engines. Several methods may be employed to reduce the viscosity of the oil.

Table 2 Properties of Crude and Raw Jatropha reported in the literature.

Author	Density @ kg/m³	Heating Value	viscosity@ 40 C°	Cetane number	Flashpoint
[23]*	932	38500	5.2	_	240
[23]**	836	39000	3.7	55	155
[24]*	921	39584	38	_	235
[24]**	881	39594	4.12	48.13	162
[13]*	910	39000	30.22	47	143
[13]**	848.2	41500	5	53	76
[25]*	920	37800	52	48	240
[25]**	880	39340	4.34	51	179
[26] *	932	37830	51	38	240
[26] **	879	38500	4.84	51	191
[21] *	932	38200	52	38	210
[27] **	885	38789	4.5	55	163
[28] *	932	38500	34		210
[28] **	879	38900	4.15	52	191

*Crude Jatropha oil
**jatropha Biodiesel

Density, viscosity, flashpoint, and calorific value are the major factors in the determination of the quality of fuel. It is evident from the table above that Jatropha possesses similar properties as that of diesel fuel. These properties make Jatropha a suitable substitute for diesel fuel. From the above table, the density of Jatropha is slightly higher than that of diesel fuel. However, this value is still within the acceptable range of ASTM standards [44].
According to Koh and Tinia (2011), Jatropha has a cetane number that ranges between 38 – 51. This range meets the ASTM standard of 45 – 55. The higher the cetane number, the shorter the delay of auto-ignition. Flashpoint is important during storage and transportation. The lower the flashpoint, the higher the chances of explosion. In comparison with diesel fuel, Jatropha has a flashpoint of 210 – 240. This means the chances of igniting are very minimal.
The kinematic viscosity of jatropha is slightly higher than that of diesel fuel. This property deals with the fluid's resistance to flow. The higher the viscosity, the higher the resistance of a fluid to flow. According to ASTM, the acceptable range is 1.9 – 6 mm/s^2. Calorific value is the total heat produced after complete combustion. This heat determines the power and torque which will be produced. The calorific value of Jatropha is like that of diesel fuel [30].

C. Production of biodiesel
Vegetable oils are naturally complex chemically and are esters of fatty acids. Their density ranges from 800kg/m^3 or more and has a very high viscosity. Because of this, it makes it impossible for them to be utilized by engines as fuels. For this oil to be considered as fuel for engines, the molecules need to be broken down into simple molecules. This process makes vegetable oils to be lighter, and the viscosity and properties becomes like that of standard diesel. Several methods can be employed to produce clean and light vegetable oil which can be used as fuel. The methods are dilution, micro emulsification transesterification, and pyrolysis [31].

a) Micro-emulsion
The reduction of vegetable oils may be reduced by microemulsion process. This amphiphilic method consists of hydrous phase, oily phase, it is stable thermodynamically and isotropic. The addition of butanol and pentanol as co-surfactant ensures that this ternary phase its maximum viscosity for diesel engines [29].

b) Pyrolysis
Pyrolysis is a process that involves splitting of chemical bonds into smaller molecules by means of heat or a catalyst with the absentia of air or oxygen [32]. Applied pyrolysis method to reduce the viscosity of soyabean oil. Though the results were not 100%, the viscosity was within the acceptable range.

c) Blending or Dilution
Blending method is when vegetable oil with diesel fuel to reduce the viscosity of vegetable oil. This method is employed to diesel engine as to enhance combustion and to lower exhaust emissions. Franco (2011) [33] studied a 50/50 blend of rapeseed oil and diesel. Studies have proved to be a reasonable substitute for diesel. Slight improvements were spotted in the combustion chamber and hydrocarbon emissions have shown positive results. However coking and excessive carbon deposits were evident.

d) Transesterification
Transesterification process whereby raw vegetable oil is mixed with alcohol and catalyst to produce lightweight oil called biodiesel. It Consists of three consecutive orders, triglycerides, di glycerides, monoglycerides, and glycerol [30]. The process requires the addition of alcohol to prevent the formation of soap and poor yield. The most widely used alcohols are Methanol and Ethanol. However, methanol is preferred most than ethanol due to its physical and chemical properties [31]. A catalyst is required to speed up the process and ensure that the final product is

efficient and effective. A catalyst can be acidic or base catalyst.

Acid catalyst
An acidic catalyst has a very high yields in alkali esters. Sulfonic and sulphuric acids are preferably the favourites in this process. However, acidic catalyst requires 3 hours or more for the conversion to complete. This process operates in temperatures which are 100°C or more [34].

Base Catalyst
Base transesterification process is the most favoured one due to its corrosive resistance and because it is faster than acid catalyst. Sodium and potassium carbonates are the preferred alkaline [29]. Among the list of catalyst, potassium hydroxide has been the most preferred one due to its cost effectiveness [35].

D. Advantages and disadvantages of Biodiesel
Researchers weighed the advantages of biodiesel and observed that it can best substitute diesel fuel. The studies showed that biodiesel is biodegradable, non-toxic, environmental friendliness, and non-flammable. It has the ability to reduce the carbon monoxide emission. It is renewable and can be used with engines with little or no modifications [18].
However, the downside of using biodiesel has been on the costs to use it. Currently its costs are more expensive than diesel fuel. Mofijur et al. (2013) [18] reported that NOx emission is higher than that of diesel and evident of clogging have been observed.

III. Engine performance, combustion and emission characteristics when fuelled with Jatropha Biodiesel.

Engines in most cases are selected based on the capital cost and running costs. However, because of comparison between engine, factors like power and speed plays a vital role in the selection of the best engine. Among these factors, Brake power, Brake thermal efficiency, and Specific fuel consumption will be discussed [37].
Considerable number of researchers have reviewed the use of Jatropha biodiesel as an alternative for diesel fuel. Non-edible feedstock has been employed by several researchers and have yielded positive results with transesterification method. This is because the yield of biodiesel depends upon the method, quantity, temperature, and the type of catalyst used. Jatropha biodiesel proved to have properties that are closer to those of diesel fuel. These properties make it easy to use non-edible biodiesel as substitute for diesel or as blends with diesel. This can be achieved without any engine modification.

The conducted investigations were carried out with the objective of studying the engine combustion, performance (Brake power, Break thermal efficiency and Brake specific fuel combustion), and the emission characteristics (CO, HC, and NO_x).

A. Engine performance parameters.
a) Brake power
Brake power is the power produced by the engine. With the engine connected to a loaded dynamometer, the torque exerted by the engine helps us to identify the power produced. The more the brake power, the faster it will be [38].
Khalid *et al.* (2015) [39], observed evidence of increase in brake power which resembles the findings in diesel fuel. This increase is evident from 1500rpm to 3000rpm. However, Paul, Datta and Mandal (2014), observed that Jatropha biodiesel blends (JB10, JB20, JB50, and JB100) reported a decrease in brake power. JB20 recorded the best brake power at around 2.64% more than that of diesel fuel [41]. This decline of brake power decreases with an increase in jatropha composition. The cause of this decrease may be due to low heating value of jatropha biodiesel.
[27], records 0.09 – 2.64% higher than diesel when JB20 is being used on a single cylinder, 4 stroke diesel engines. This blend showed an increase in BTE. However, these results decrease with an increase in the percentage of biodiesel.

b) Brake Specific Fuel Consumption
Specific fuel consumption is the consumption rate of fuel per power produced. This criterion helps determine how much fuel is consumed and compares to the power produced [42]
Various tests have been conducted with different blends of Jatropha biodiesel and diesel. These tests were done at different loads. Higher proportions of Jatropha biodiesel results in higher viscosity which causes poor atomization. Poor atomization led to increase in specific fuel consumption. However, when 20% jatropha biodiesel (JB20) is mixed with diesel fuel positive results are evident. B20 led to specific fuel consumption which is like that of Diesel fuel. Chukwuezie et al., [38]observed the results of 100% Jatropha biodiesel (JB100). It was evident that JB100 showed an increase in BSFC due to high density of the biodiesel. This increase has proved to be higher than that of diesel fuel.
Chauhan, Kumar, and Cho [24], reported a higher brake specific fuel consumption because of the effects of increased density, viscosity, and heating value.

c) Brake thermal efficiency
The importance of brake thermal efficiency is in indicating how much percentage of fuel has been consumed to produce useful output power [40]. Brake thermal efficiency for all jatropha biodiesel blends turned to be lower than that of diesel fuel. 20% Jatropha blends recorded an efficiency which is closer to that of diesel. This occurred at a break power of 3.9 kW. As the percentage of Jatropha increases the efficiency shows a decline. Poor atomization may the leading factor of this decline [39]. According to Chauhan, Kumar and Cho (2012) [24], jatropha biodiesel and its blends records an efficiency that is lower than that of diesel. This may be caused by high fuel consumption and lower heating value.

However, Chukwuezie *et al.* [38] observed that when 10% to 30% of Jatropha biodiesel is used , there is an increase in brake thermal efficiency. However, as soon as the volume of jatropha exceeds 30% a decrease is evident again.

B. Engine combustion

When Chauhan *et al.* (2012) [24] observed the operation of diesel engine run with Jatropha biodiesel and its blends (JB20, JB40, JB80, and JB100) it was noted that Jatropha has shorter ignition delay, and the gas cylinder pressure was lower than in diesel fuel. Higher cetane number in Jatropha enhances combustion of diesel engine. This is made possible because of excess of oxygen in Jatropha biodiesel [39]. When Mofijur *et al.* (2013) [18] studied the effects of 100% Jatropha biodiesel, complete combustion was evident and higher cetane number played a big role in the reduction of ignition delays. Lower cylinder pressure and heat release rate was observed in 100% Jatropha biodiesel than diesel Fuel. The investigations performed by Chukwuezie *et al.*, [38] indicated that the exhaust gas temperature of Jatropha biodiesel is lower than of diesel fuel. As this exhaust is released, it burns in air and release carbon dioxide which is useful in plant for photosynthesis process.

C. Engine emission

Globally, vehicles are the responsible for polluting the quality of air through exhaust emission. The process of combustion results in direct emission of exhaust gas components which in turn pollutes the environment. Exhaust pollutants may be divided into harmful and harmless components. These components may be unavoidable or be subjects to limits. Harmless exhaust gases include oxygen which is useful to the environment. Harmful components emitted during the combustion process are carbon monoxide, unburned hydrocarbons, nitrogen oxides, sulphur compounds, and particulates matter (1)

a) Carbon Monoxide (CO)

The presence of CO indicates incomplete combustion. Excess concentration of CO in the ambient has an ability to affect the haemoglobin which results in low oxygen in the blood [43].

Since vegetable oils are highly oxygenated fuel which ensure complete combustion in the engine. As a result of this unburned HC and particulates are low for Jatropha as compared to diesel fuel. However, a slight increase in unburned HC and particulates with increase of load. Complete combustion ensures a decrease of CO emission. Nevertheless, as the engine load increases it results in increase in combustion temperature. An increase in combustion is directly proportional to the emission of NO_x. A slight increase in CO2 is evident, nonetheless high carbon dioxide enhances photosynthesis in plant [24]. Ashraful AM et.al., [41], Studied the effects of different blends (JB10, JB20, JB50, and JB100) of jatropha. This study was done on different loads (20%, 40%, 60%, 80%, and 100%). The percentage of CO emission decreases with the increase in biodiesel ratio.

b) Nitrogen Oxides (NO_x)

NOx occurs because of insufficient oxygen and low temperatures. These conditions result in slow reaction. NOx emissions cause lung irritation and weak resistance to infection of the respiratory system [44].

According to [25], the use of 100% jatropha biodiesel in different loading conditions results in higher NOx emissions. This is because of the presence of higher oxygen content in the combustion chamber. Prabhu, et al. (2018) [30] researched the effect of 100% Jatropha biodiesel on the engine, the results indicated that as the load increase so is the NOx emission.

c) Hydrocarbons (HC)

When fuel molecules are unburned or partially burned it leads to HC emission. Low concentrations of HC are not that harmful. However, higher concentration of HC is known to be carcinogenic [43]. Since vegetable oils are highly oxygenated fuel, this ensures complete combustion in the engine. As a result of this unburned HC and particulates are low for Jatropha biodiesel as compared to diesel fuel [44].

Tan *et al.* (2012), studied the effects of Jatropha biodiesel and it was evident that the presence of higher oxygen content in the combustion chamber results in complete combustion. Combustion delays has been reduced greatly due to higher certain number. All these results in the reduction of HC emissions from the engine.

When running a single cylinder, 4 stroke diesel engine, Ashraful *et al.* (2014) [41] recorded a decrease in hydrocarbon content. JB10, JB20, JB50 and JB100 were tested and there was 15% decrease. The results improved with an increase in jatropha concentration.

d) Particulate matter (PM)

Particulate matter in the ambient impair the breathing system and harm the respiratory system [44]. A decrease in the emission of PM was evident. As the percentage of biodiesel increases, a decrease in particulate matter is always observed [41] [23].

IV. Conclusion

In this review, Jatropha and its blends were used as fuel and operated under various loads and engine speeds. The engine ran smoothly with no unfamiliar sounds and signs. There were no modifications done on the engine. It was observed lower concentration volume of Jatropha biodiesel performed better than higher volumes. Though Jatropha biodiesel matches diesel in properties and performances, a blend of 20% and 80% diesel proves to have better performance.

It was observed that due to low calorific value, Jatropha biodiesel has lower break thermal efficiency. A slight increase in brake specific fuel consumption was recorded due to the density of Jatropha biodiesel. This means more Jatropha fuel will be consumed. The density of Jatropha biodiesel affected the Brake power due to poor atomization. However, a decrease in exhaust gas temperature has been reported when using Jatropha biodiesel. This is because of higher content of oxygen in the engine. Higher CO2 is evident but useful for plants photosynthesis.

HC, smoke, and CO have reportedly decreased with the use Jatropha biodiesel. This decrease is evident mostly with the use of 20% Jatropha biodiesel. The presence of oxygen ensures complete combustion. However, NOx emission reportedly increased. As the engine speed increases, it results in a decrease in NOx and in increase in smoke.

The review proves that Jatropha biodiesel may be used at a small ratio as alternative for diesel engine. the engine ran without modification and no fault was reported. However, research may be conducted to improve the power output, fuel consumption and the reduction of NO_x.

Reference

[1] S. Firoz, A review: Advantages and disadvantages of biodiesel, Int. Res. J. Eng. Technol., 4 (11) (2017) 530–535 [Online]. Available: www.irjet.net.

[2] A. Murugesan, C. Umarani, R. Subramanian, and N. Nedunchezhian, Bio-diesel as an alternative fuel for diesel engines-A review, Renew. Sustain. Energy Rev., 13 (3) 653–662, , doi: 10.1016/j.rser.2007.10.007.

[3] H. M. Mahmudul, F. Y. Hagos, R. Mamat, A. A. Adam, W. F. W. Ishak, and R. Alenezi, Production, characterization and performance of biodiesel as an alternative fuel in diesel engines – A review, Renew. Sustain. Energy Rev., 72 (2016) 497–509, 2017, doi: 10.1016/j.rser.2017.01.001.

[4] K. J. Godri Pollitt, D. Chhan, K. Rais, K. Pan, and J. S. Wallace, Biodiesel fuels: A greener diesel? A review from a health perspective, Sci. Total Environ., 688 (2) (2019) 1036–1055 doi: 10.1016/j.scitotenv.2019.06.002.

[5] E. I. Onuh, F. Inambao, and O. Awogbemi, Performance and emission evaluation of biodiesel derived from waste restaurant oil and Moringa oleifera: a comparative study, Int. J. Ambient Energy, 0(0) (2019) 1–8 doi: 10.1080/01430750.2019.1594377.

[6] H. Suhaimi et al., Analysis of combustion characteristics , engine performances and emissions of long-chain alcohol-diesel fuel blends, Fuel, 220(1) (2018) 682–691, doi: 10.1016/j.fuel.2018.02.019.

[7] N. Asikin-Mijan et al., Production of renewable diesel from Jatropha curcas oil via pyrolytic-deoxygenation over various multi-wall carbon nanotube-based catalysts, Process Saf. Environ. Prot., 142 (2020) 336–349, doi: 10.1016/j.psep.2020.06.034.

[8] C. C. Enweremadu and H. L. Rutto, Combustion, emission and engine performance characteristics of used cooking oil biodiesel - A review, Renew. Sustain. Energy Rev., 14(9) (2010) 2863–2873, doi: 10.1016/j.rser.2010.07.036.

[9] M. M. Gui, K. T. Lee, and S. Bhatia, Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock, Energy, 33(11) (2008) 1646–1653, doi: 10.1016/j.energy.2008.06.002.

[10] The Development of the Diesel Engine Author (s): Lynwood Bryant Published by : The Johns Hopkins University Press and the Society for the History of Technology Stable URL : https://www.jstor.org/stable/3103523 REFERENCES Linked references are available, 17 (3) (1976) 432–446.

[11] B. S. Chauhan, N. Kumar, H. M. Cho, and H. C. Lim, A study on the performance and emission of a diesel engine fueled with Karanja biodiesel and its blends, Energy, 56 (2013) 1–7, doi: 10.1016/j.energy.2013.03.083.

[12] K. Kannan and M. Udayakumar, Experimental study of the effect of fuel injection pressure on diesel engine performance and emission, J. Eng. Appl. Sci., 5(5) (2010) 42–45.

[13] M. S. Gad, A. S. El-Shafay, and H. M. Abu Hashish, Assessment of diesel engine performance, emissions and combustion characteristics burning biodiesel blends from jatropha seeds, Process Saf. Environ. Prot., 147 (2021) 518–526, doi: 10.1016/j.psep.2020.11.034.

[14] A. Jamrozik, "The effect of the alcohol content in the fuel mixture on the performance and emissions of a direct injection diesel engine fueled with diesel-methanol and diesel-ethanol blends," *Energy* Convers. Manag., 148, pp. 461–476, 2017, doi: 10.1016/j.enconman.2017.06.030.

[15] Erdiwansyah, R. Mamat, M. S. M. Sani, K. Sudhakar, A. Kadarohman, and R. E. Sardjono, An overview of Higher alcohol and biodiesel as alternative fuels in engines, Energy Reports, 5 (2019) 467–479, doi: 10.1016/j.egyr.2019.04.009.

[16] B. Rajesh Kumar and S. Saravanan, Use of higher alcohol biofuels in diesel engines: A review, Renew. Sustain. Energy Rev., 60 (2016) 84–115, doi: 10.1016/j.rser.2016.01.085.

[17] T. Ashok Kumar, R. Chandramouli, and T. Mohanraj, A study on the performance and emission characteristics of esterified pinnai oil tested in VCR engine, Ecotoxicol. Environ. Saf., 121 (2015) 51–56, doi: 10.1016/j.ecoenv.2015.06.008.

[18] M. Mofijur, A. E. Atabani, H. H. Masjuki, M. A. Kalam, and B. M. Masum, "A study on the effects of promising edible and non-edible biodiesel feedstocks on engine performance and emissions production: A comparative evaluation," Renew. Sustain. Energy Rev., 23 (2013) 391–404, doi: 10.1016/j.rser.2013.03.009.

[19] I. Ambat, V. Srivastava, and M. Sillanpää, Recent advancement in biodiesel production methodologies using various feedstock: A review, Renew. Sustain. Energy Rev., 90(2) (2017) 356–369, doi: 10.1016/j.rser.2018.03.069.

[20] D. H. Qi, H. Chen, L. M. Geng, and Y. Z. Bian, Experimental studies on the combustion characteristics and performance of a direct injection engine fueled with biodiesel/diesel blends, Energy Convers. Manag., 51 (12) (2010) 2985–2992, doi: 10.1016/j.enconman.2010.06.042.

[21] K. Pramanik, Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine, Renew. Energy, 28 (2) (2003)239–248. doi: 10.1016/S0960-1481(02)00027-7.

[22] J. C. Juan, D. A. Kartika, T. Y. Wu, and T. Y. Y. Hin, Biodiesel production from jatropha oil by catalytic and non-catalytic approaches: An overview, Bioresour. Technol., 102 (2) (2011) 452–460. doi: 10.1016/j.biortech.2010.09.093.

[23] G. Goga, B. S. Chauhan, S. K. Mahla, and H. M. Cho, Performance and emission characteristics of diesel engine fueled with rice bran biodiesel and n-butanol, Energy Reports, (2019), doi: 10.1016/j.egyr.2018.12.002.

[24] B. S. Chauhan, N. Kumar, and H. M. Cho, A study on the performance and emission of a diesel engine fueled with Jatropha biodiesel oil and its blends, Energy, 37(1) (2012) 616–622., doi: 10.1016/j.energy.2011.10.043.

[25] P. qiang Tan, Z. yuan Hu, D. ming Lou, and Z. jun Li, Exhaust emissions from a light-duty diesel engine with Jatropha biodiesel fuel, Energy, 39 (1) (2012) 356–362, doi: 10.1016/j.energy.2012.01.002.

[26] D. Singh et al., A comprehensive review of physicochemical properties, production process, performance and emissions characteristics of 2nd generation biodiesel feedstock: Jatropha curcas, Fuel, 285(4) (2020), 119110. doi: 10.1016/j.fuel.2020.119110.

[27] A. Prabhu, M. Venkata Ramanan, and J. Jayaprabakar, Production, properties and engine characteristics of Jatropha biodiesel – a review, Int. J. Ambient Energy, 0750 (2018) 1–5. doi: 10.1080/01430750.2018.1557548.

[28] A. Samniang, C. Tipachan, and S. Kajorncheappun-ngam, Comparison of biodiesel production from crude Jatropha oil and Krating oil by supercritical methanol transesterification, Renew. Energy, 68 (2014) 351–355 doi: 10.1016/j.renene.2014.01.039.

[29] M. Y. Koh and T. I. Tinia, A review of biodiesel production from Jatropha curcas L. oil, Renew. Sustain. Energy Rev., 15 (5) (2011) 2240–2251. doi: 10.1016/j.rser.2011.02.013.

[30] A. Prabhu, M. Venkata Ramanan, and J. Jayaprabakar, Production, properties and engine characteristics of Jatropha biodiesel – a review, Int. J. Ambient Energy, 0(0) (2018) 1–5 doi: 10.1080/01430750.2018.1557548.

[31] S. Rani, S. Kaur, . S., and H. Kaur, Production of Biodiesel from Non- Edible Oil (WCO), Int. Res. J. Sci. Technol., 3 (4) (2020) 268–271, , doi: 10.46378/irjst.2020.010313.

[32] A. W. Schwab, M. O. Bagby, and B. Freedman, Preparation and properties of diesel fuels from vegetable oils, Fuel, 66 (10) (1987) 1372–1378. doi: 10.1016/0016-2361(87)90184-0.

[33] Z. Franco and Q. D. Nguyen, Flow properties of vegetable oil-diesel fuel blends, Fuel, 90 (2) (2011) 838–843, doi: 10.1016/j.fuel.2010.09.044.

[34] U. Schuchardt, R. Sercheli, and R. Matheus, Transesterification of Vegetable Oils : a Review General Aspects of Transesterification Transesterification of Vegetable Oils Acid-Catalyzed Processes Base-Catalyzed Processes, J. Braz. Chem. Soc., 9 (1) (1998) 199–210.

[35] P. D. Patil and S. Deng, Optimization of biodiesel production from edible and non-edible vegetable oils, *Fuel*, 88(7) (2009) 1302–1306. doi: 10.1016/j.fuel.2009.01.016.

[36] M. Mofijur et al., Effect of biodiesel from various feedstocks on combustion characteristics engine durability and materials compatibility: A review, Renew. Sustain. Energy Rev., 28 (2013) 441–455, , doi: 10.1016/j.rser.2013.07.051.

[37] R. A. Bakar, Semin, and A. R. Ismail, Investigation of diesel engine performance based on simulation, Am. J. Appl. Sci., 5 (6) 610–617, 2008, doi: 10.3844/ajassp.2008.610.617.

[38] O. C. Chukwuezie, K. N. Nwaigwe, S. N. Asoegwu, and E. E. Anyanwu, Diesel engine performance of jatropha biodiesel: A review, Biofuels, 5(4) (2014) 415–430. doi: 10.1080/17597269.2014.986416.

[39] A. Khalid et al., Performance and emissions characteristics of crude jatropha oil biodiesel blends in a diesel engine, Int. J. Automot. Mech. Eng., 11 (1), pp. 2447–2457, 2015, doi: 10.15282/ijame.11.2015.25.0206.

[40] G. Paul, A. Datta, and B. K. Mandal, An experimental and numerical investigation of the performance, combustion and emission characteristics of a diesel engine fueled with jatropha biodiesel, Energy Procedia, 54 (2014) 455–467. doi: 10.1016/j.egypro.2014.07.288.

[41] A. M. Ashraful et al., Production and comparison of fuel properties, engine performance, and emission characteristics of biodiesel from various non-edible vegetable oils: A review, Energy Convers. *Manag.*, 80 (2014) 202–228. doi: 10.1016/j.enconman.2014.01.037.

[42] P. V. K. Murthy and M. V. S. M. Krishna, Performance , Emissions and Combustion Characteristics of Mohr Oil in Crude and Biodiesel Form in High Grade Low Heat Rejection Diesel Engine, Int. J. Sci. Eng. Technol. Res., 3 (6) (2013) 215–227.

[43] M. M. Hasan and M. M. Rahman, Performance and emission characteristics of biodiesel–diesel blend and environmental and economic impacts of biodiesel production: A review, Renew. Sustain. Energy Rev., 74(2) (2017) 938–948. doi: 10.1016/j.rser.2017.03.045.

[44] M. Mofijur, M. Rasul, N. M. S. Hassan, and M. N. Uddin, Investigation of exhaust emissions from a stationary diesel engine fuelled with biodiesel, Energy Procedia, 160 (2019) 791–797, doi: 10.1016/j.egypro.2019.02.159.