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Review Article

Impact of Biodiesel Engine Performance on Operations and the Environment: A Literature Review

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ABSTRACT

Fossil fuels have posed a great danger to the existence of living things in the world, and pollution is wreaking havoc on the planet's ecosystems. Global fuel consumption has risen precipitously because of urbanization, industrialization, and an ever-increasing human population. It has become necessary to consider alternatives to petroleum-based fuels such as diesel and gasoline considering our current overdependence on these traditional sources of energy. In this scenario, biodiesel presents an excellent opportunity. Biodiesel is highly replicable since it is made mostly from renewable resources, such as food and non-edible plants. Biodiesel cannot be used directly in engines because of its high viscosity. The relevant literature is categorized in this study. This research also tries to highlight the benefits of utilizing biodiesel and the advances made by researchers. Various articles about biodiesel fuel and its blends in diesel and engines were gathered and sorted depending on the blending techniques used (complete substitution without diesel or partial substitution). The use of biodiesel in engines and its ability to compete with fossil fuel diesel in performance were among the topics covered in this research. Biodiesel's effect on engine performance and environmental impact will be examined in this article. The study reveals that B20 biodiesel will be a replacement for fossil fuel diesel as an alternate fuel. The results reveal that the brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) for B20 biodiesel are identical to diesel and hence can serve as a potential alternative to petroleum-based fuels.

Keywords: biodiesel, BSFC, BTE, emission, performance

INTRODUCTION

Energy consumption has skyrocketed to keep up with rising standards of living and economic expansion since the industrial revolution began in earnest throughout the globe. Energy demands have been met mostly by fossil fuels including coal, petroleum, and natural gas in previous decades. Fossil fuels will be depleted in the near future at the current pace of use. We must explore beyond traditional fuel sources and create alternative fuels at this critical juncture. As an alternative fuel, biodiesel is an excellent option. Diesel engines have been widely used in recent decades because of their cheaper running costs, improved thermal efficiency, and longer lifespan. Diesel engines, on the other hand, produce more NO_x and PM than gasoline engines. As a result, the environment is at danger in the long term from the widespread usage of diesel engines. Acid rain, photochemical smog, global warming, nose, and eye discomfort, and sight impairment may all be caused by high NOx, HC, or CO emissions (Talebizadeh et al., 2014). The amount of pollution in the atmosphere must be minimized. CO and HC emissions are lower in diesel engines, while NOx and particulate matter emissions are greater. The fact that biodiesel is an oxygenated fuel means that it burns completely, emits less pollutants, and has a lower environmental impact. Some studies have shown high levels of CO and NOx emissions; others have found low levels of CO, HC, and smoke emissions. In a heavy load situation, CO emissions drop by 4-46.5%. HC emission is reduced when the fuel mix has a low proportion of biodiesel and when the vehicle is under a heavy load. Fuel blends containing more biodiesel tend to have lower levels of particulate matter. As the amount of biodiesel in the fuel mix grows, NOx emissions rise by 4.15-14.18% and reduced by 4-39% when a low biodiesel proportion is included in the fuel mix though. High engine loads and a high biodiesel content in the fuel mix reduce smoke levels by (20-43%) (Ashraful et al., 2014; Sahoo et al., 2009).

Mahua biodiesel has minimal emissions of CO, HC, NOx, and smoke, but it may also produce significant levels of NOx. Increased biodiesel proportion in the fuel mix reduces CO emissions by 0.02-0.16%. The HC emission falls by 35-60 percent with the rise in the proportion of biodiesel in the fuel mix and at high engine loads. Increased engine load and a high biodiesel content led to an increase in NOx emissions of 6-

Table 1. Production of biodiesel feedstocks in different countries (Daud et al., 2015)

Country	Oil feedstock
Philippines	Coconut oil
India	Jatropha curcas oil
Indonesia	Palm oil
China	Waste cooking oil
Thailand	Palm oil
Malaysia	Palm oil

16%. Using mahua ethyl ester, the reduction is 9-27%. Using a high amount of biodiesel in a fuel mix reduces smoke production (5-46%). (Agarwal et al., 2008). Many nations are turning to biodiesel and vegetable oils as alternatives to traditional liquid fuels due to the rapid decline in crude oil stocks. The primary determinants of feedstock selection are climate and soil characteristics. Soybean oil, for example, is favored in the United States, although rapeseed and sunflower oils are popular in Europe, palm oil is used in Southeast Asia (particularly in Malaysia and Indonesia), and coconut oil is being investigated as a replacement to diesel in the Philippines. (Puhan et al., 2009) (**Table 1**).

Linseed biodiesel shows low CO, HC, NOx, and smoke emissions are also a plus for the fuel's emissions. A high percentage of biodiesel in fuel blends and a high engine load condition reduce CO emissions. Linseed biodiesel emits more hydrocarbons (HC) when it is blended with more biodiesel and has a greater load. The amount of HC emissions drops significantly as the amount of gasoline used increases.

When using a high proportion of biodiesel in the fuel mix, NOx emissions tend to rise. Fuel injection pressure increases NOx emissions while lowering smoke levels. Using jatropha biodiesel resulted in low emissions of CO, HC, NOx, and smoke opacity. Engine load with EGR operation increases CO and HC emissions, although biodiesel proportion in fuel blends progressively reduces them. Because of the high biodiesel percentage in fuel blends, CO emission drops by 5.57-35.21% and HC emissions lowers by 14.91-32.28%. EGR operation reduces NOx emissions, however higher engine load and biodiesel concentration in fuel blends increase NOx emissions. Under some circumstances, NOx emissions might rise by 3.29-10.75%. However, in a fully loaded situation, it decreases. Fuel mixes with more biodiesel tend to have lower levels of smoke opacity than those with less biodiesel (Huang et al., 2010). The purpose of this study is to examine the various techniques of producing biodiesel from various feedstocks, to compare the various fuel attributes to pick the best among various vegetable oils and to compare them on the basis of performance and emission characteristics. A better understanding of the practicality of biodiesel for use in diesel engines and its environmental effect may be gained from this data set. The goal of this study is to eliminate the gaps in biodiesel production by using various feedstocks and selecting them based on the findings of literature.

THE GLOBAL ENERGY SCENE

In the last several decades, as a result of fast worldwide expansion in industrialization, development of people, and population growth, energy needs have risen to unprecedented levels. The amount of energy available has gradually risen over the previous 25 years. At current consumption rates, crude oil and natural gas resources will be depleted in about 41.8 and 60.3 years, respectively. As much as four billion metric tons of crude oil reserves disappear each year. By 2052, oil reserves will be depleted if this pace continues. (Singh et al., 2012).

Oil and coal still account for 67% of total energy supply, despite the fact that their proportion has declined from around 67.2% in 2010 (as shown in **Figure 1**), which shows the major fuels' contribution in total primary energy supply (TPES).

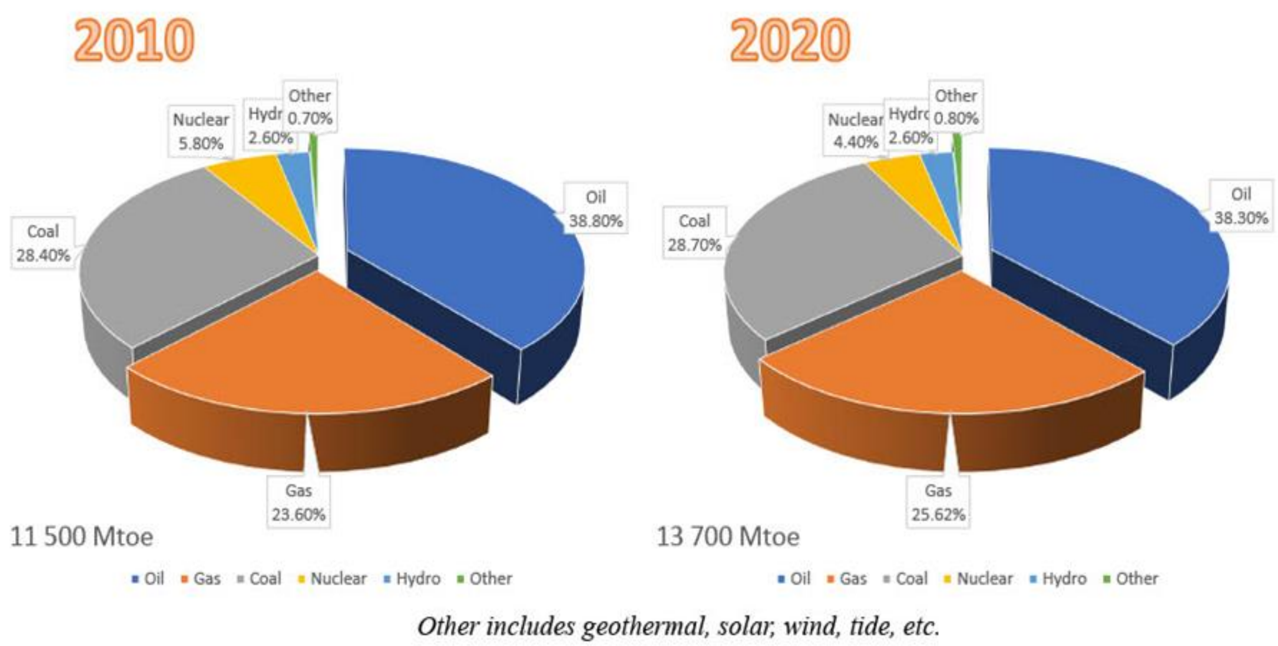

Figure 1. Shares of world total energy consumption of fuel (IEA et al., 2022)

USING BIODIESEL AS A REPLACEMENT FUEL

The use of biodiesel as a replacement for petroleum is due to its high viscosity, vegetable oil is not advised for use in a diesel engine. To address this problem, biodiesel is transformed into a form that is engine-friendly to a degree. Biodiesel may be made from vegetable oil in one of four ways:

1. Direct use and blending,
2. Micro-emulsion,
3. Pyrolysis, and
4. Transesterification.

Using Directly and Mixing as a Fuel Source

Vegetable oils may be directly used. It's possible to utilize oil in a combination or in its purest form. Fueling a vehicle with vegetable oils has a number of advantages:

1. The ability to be transported easily,
2. The high heat content (about 80% of diesel fuel),
3. Sustainability and renewability, and
4. The quantity of the fuel.

In the end, the results are not good enough, and researchers don't think the procedure is very useful. There are many drawbacks to using vegetable oils as fuels, including high viscosity, low volatility, and the presence of free fatty acids.

Even with direct-injection engines, these issues only develop after the engine has been running on vegetable oils for a lengthy period of time.

Micro-Emulsion

An example of a micro-emulsion might be water, oil, and an amphiphile combine to form a micro-emulsion that is both optically isotropic and thermodynamically stable. When vegetable oil is too viscous, a micro-emulsion of oil with some alcohol such as methanol, ethanol and 1-butanol may be used.

Incomplete combustion of fuel was the primary source of this problem's damaging exhaust gas emissions. Emulsions make it harder to get a steady fuel.

The Pyrolysis of a Substance

Pyrolysis is the use of heat to change one material into another, sometimes with the aid of a catalyst, and usually without the presence of oxygen. Natural fatty acids or methyl esters of natural fatty acids may also be paralyzed (Ma and Hanna, 1999).

Reduced oil stability renders it inappropriate for engine operation as a consequence of pyrolysis.

Transesterification

This section deals with the process of transesterification. Triglycerides, such as vegetable oil, are combined with alcohol and a catalyst to form fatty acid esters and glycerol during transesterification. As a result of their cheap cost, physical and chemical benefits, methanol, as well as ethanol, are common alcohols. Triglycerides readily dissolve and react with them. For a reaction to be completed in a short period of time, a catalyst is also required. Transesterification involves reacting triglyceride with alcohol using a catalyst. Vegetable oil methyl ester (also known as biodiesel) is used in place of the glycerol found in the oil to produce this biodiesel replacement. Glycerol is formed in small amounts during the transesterification event, amounting to around 10% of the total fatty acid weight.

Table 2. Different sources of biodiesel

Edible oils	Non-edible oils	Other sources
Cotton seed oil	Jatropha curcas seed oil	Algae
Castor oil	Pongamia	Waste cooking oil
Soybean	Mahua	Animal fats
Coconut oil	Neem	
Rapeseed	Eucalyptus	

BIODIESEL'S SOURCE

Feedstock preparation of biodiesel can be broadly classified into three categories:

1. Edible oils,
2. Nonedible oils, and
3. Other sources.

Biodiesel may be made from a variety of edible oils, including coconut, rapeseed, and canola oils (**Table 2**). Mahua, neem, jatropha, pongamia, and eucalyptus are the most common sources of non-edible oils. A new biodiesel source has emerged in recent years: algae. Biodiesel was formerly made mostly from vegetable oils, most notably canola and palm. Crop land is the primary source of most edible oils. The disadvantages of making biodiesel from vegetable oils have an adverse effect on agricultural crops and the environment as a whole. Large-scale biodiesel production requires a lot of farmlands. The impact on the global food supply will be significant if the same policy is implemented globally. Using non-edible oils for biodiesel production is the greatest available alternative to address this problem. This means that oils from non-edible plants, like eucalyptus, mahua, and jatropha will be significant for biodiesel production as a non-edible plant oil source (Dwivedi and Sharma, 2014a).

Vegetable Oils and Their Fuel-Energy Properties

Biodiesel and other biofuels from plant oils castor, canola, cottenseed, rapeseed, and soyabean were chosen as edible oils while mahua, neem, jatropha, pongamia, and eucalyptus were chosen as non-edible oils for comparison with the qualities of petroleum diesel. The abundance of these oils as a fuel source in India is a major factor in their selection. Higher viscosity is the primary issue that emerges when using vegetable oil in lieu of diesel. Carbon deposits have been seen on injectors and valve seats owing to the high viscosity of the fluid. Incomplete combustion and inadequate fuel atomization are further consequences. Carbon deposits on the piston rings and cylinder wall cause the lubricating fluid to dilute and thicken, which may damage or cause the failure of mechanical components in the engine (Dwivedi and Sharma, 2014b).

Table 3 lists the kinematic viscosity of most oils except eucalyptus oil, which varies from 22 (at 30°C) to 55 (at 38°C) while the highest kinematic viscosity of diesel is four. To get around the oil's high viscosity, several procedures including

Table 3. Vegetable oils and their fuel-energy properties

Oil type	Vegetable oils	Specific gravity at 150°C	Kinematic viscosity (cSt) (38°C)	Flashpoint (°C)	Cetane number	Heating values (MJ/kg)	Cloudpoint (°C)	Pourpoint (°C)
Edible oils	Rapeseed	0.911	37.0	246	37.6	39.7	-3.9	-31.7
	Cottonseed	0.914	33.5	234	41.8	39.5	1.7	-15.0
	Castor	0.970	29.7	229	51.2	39.7	-11.6	-31.7
	Canola	0.916	20.6	232	40	25	-3.9	-31.6
	Soyabean	0.913	32.6	254	37.9	39.6	-3.9	-12.2
Non-edible oils	Pongamia	0.882	55	110	51	46	23	-
	Mahua	0.880	30.4	226	52.4	41.82	13	15
	Eucalyptus	0.913	2	53	-	43.27	-	-
	Neem	0.961	22.6	175	32	40	22	11
	Jatropha	0.912	55	240	40-55	39-40	16	-
Petroleum	Diesel	0.82-0.86	1.3-4.1	60-80	40-55	42	-15 to -5	-33- to -15

preheating the oil are necessary. For food oils, canola oil in edible oils and eucalyptus in nonedible oils have the lowest viscosity so they may be used as fuel. Most oils' heating values are found to be equivalent to those of diesel.

EXAMINING THE DATA

Biodiesel made from vegetable oil is tested on diesel engines. In the course of testing, biodiesel is typically examined in the context of various blends. Biodiesel is often tested in the form of blends, such as B_{xx}, which refers to a biodiesel mix with xx% biodiesel in plain diesel. Main performance characteristics are typically investigated, including brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), brake power, brake torque, and brake thermal energy consumption. Performance is affected by a variety of factors, including the air-fuel mixture, fuel injection pressure, fuel spray pattern, and fuel characteristics. **Table 4** and the following discussion will go over some of the engine performance characteristics that may be found in the relevant literature.

A 4-stroke water-cooled direct-injection diesel engine was used by Panwar et al. (2010) to test castor biodiesel. The findings showed that, for all blends, BSFC declined as the load increased. Biodiesel B10 has a lower BSFC than diesel for all loads when used at a low percentage. In retrospect, BSFC was found to be higher than diesel in B20 blends.

A study by Dhar and Agarwal (2014) indicated that BSFC was lower in Karanja biodiesel than in mineral diesel. BSFC was shown to be growing, despite the fact that it included a larger percentage of biodiesel. While diesel fuel practically plateaued at greater loads, higher biodiesel blends had less BTE in than diesel at lower loads. Biodiesel mixes emit less CO at higher engine speeds and loads than pure diesel. BSCO emissions of greater biodiesel mixes were higher than mineral diesel even at lower engine loads. The BSFC of soybean biodiesel rose as the biodiesel mix percentage increased. There were 2, 4, 7, and 9% higher average BSFC values over the whole range of rpms for the B10 and B50 blends than for the B20 and B10 blends compared to diesel (Ozener et al., 2014).

Using biodiesel in a vehicle's engine may have a significant influence on its performance because of its high viscosity and reduced calorific value. This has a significant performance impact on the spray production and burning of the fuel.

At various speeds, Roy et al. (2013) found that canola oil biodiesel had efficiency similar to diesel. Fuel conversion efficiency with up to 5% mixes compared to diesel at all engine speeds is nearly identical. However, as the biodiesel content rises, when compared to diesel operation, efficiency improved by 1% to 5%. Because of the greater heating values of biodiesel blends, a rise in their efficiency resulted in less BSFC than would have been expected. Using biodiesel as a comparison to diesel, it is clear that the combustion of mixed fuels is more efficient than that of diesel.

CONCLUSION

There has been a great deal of investigation into the use of biodiesel in diesel engines due to the advantages it provides in terms of both economics and the environment, as well as the fact that it is derived from a renewable resource. The effects on engine performance, emission, and characteristics were reviewed according to various operation conditions, different engine tests, reference diesel fuel tests, and various measurement techniques. Following the end of this study, biodiesel derived from both edible and non-edible oils is reviewed in this paper and the following conclusions can be drawn:

1. The B_{20} blend was determined to be the most appropriate of all the mixes.
2. According to BSFC research, the amount of BSFC in biodiesel rises in comparison to plain diesel as volume increases. Biodiesel's BTE is lower than that of pure biodiesel because of this tendency.
3. CO and HC emissions drop and improve as the amount of biodiesel in the fuel mix increases, however, NOx emissions rise as a result of utilizing biodiesel.
4. Biodiesel prepared from non-edible oils has been found more suitable as it will not affect food requirements.

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Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to corresponding author.

Table 4. Results received from a variety of sources on biodiesel performance characteristics

S/N	Fuel	BSFC	BTE	Emission characteristics	Main finding	Reference
1	Castor & diesel blend	Compared to neatdiesel, B20 has 6.66 % BTE, whereas neatdiesel has 25.31 % BTE.	Compared to neatdiesel, B20 has 6.66 % BTE, whereas neatdiesel has 25.31 % BTE.	NOx is much lower than diesel for B10, but it is significantly higher than diesel for the other mixes.	Suitable blends up to B20 have been discovered for improved engine performance.	(Panwar et al., 2010)
2	Cotton seed oil biodiesel & its blend	It was discovered that the BSFC for B20 and B40 was lower than that of diesel, however it was greater for B60 and B100.	For the B20, B40, and B60, BTE was 3.74 percent, 10.46 percent, and 3.27 percent greater than diesel.	50.44 % less smoke was produced by B100 compared to diesel at full load.	It was determined that blends up to B40 were appropriate for use in diesel engines.	(Huang et al., 2010)
3	Jatropha biodiesel	In comparison to diesel, the BSFC for B20 is 5.02 % greater.	Biodiesel's BTE was 28%, whereas B20's BTE was 27.34%	This was reduced to 3.9% with the introduction of BHT additive, and CO emissions decreased for every 5.52% increase in Jatropha biodiesel B20.	Biodiesel with a content of 20% is superior to other blends in terms of performance.	(Fattah et al., 2014)
4	Canola oil & diesel blend	Up to 10% of mixes have no effect. 1% to 2.3 % increase in BSFC when 20% mix is used.	Only mixes with less than 5% change are affected. With 10% and 20% mixes, there is a 1% to 1.5% rise in BTE	When compared to diesel, the reduction in CO and HC emissions from biodiesel–diesel mixes are substantial. Idling for long periods of time produces more than half of all NOx emissions.	Compared to diesel, biodiesel and canola oil-diesel blends have a greater fuel conversion efficiency.	(Roy et al., 2013)
5	Soybean	There were (9%) (7%) (7%) (4%) (2%) more than diesel BSFC values for the B100, B50, B20, and B10 blends.	BTE, on the other hand, is projected to be lower with greater biodiesel mixes.	Use of B10, B20, B50, and B100 reduces CO emissions by 28%, 31%, 38%, and 46%, respectively.	That's where B20 is most effective.	(Ozener et al., 2014)
6	Coconut biodiesel	B5 and B15 had an average rise of 0.53% and 2.11%, respectively.	Due to the decreased heating value of biodiesel, BTE falls.	With the rising use of biodiesel, both CO2 and NOx emissions have risen. Biodiesel reduces HC emissions.	More commonly used blends like B5, B15, and B20 have been proven to be more effective than others.	(Liaquat et al., 2013)
7	Karanja biodiesel	At 1,800 rpm, the BSFC of all three fuels was at its lowest, and then it began to rise as the engine speed climbed.	For all fuels, BTE typically rose as engine load increased.	CO emissions were found to be lower at higher engine speeds and loads, and greater at lower engine speeds and loads.	All KOME blends' BTE was almost identical to mineral diesel at greater loads.	(Dhar and Agarwal, 2014)

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