

Comparative Study of Different Biodiesel and its Operating Characteristics: Review Study

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Abstract

The uncertain availability and rising price of conventional fuels have caused research to shift away from producing conventional fuels and towards producing renewable fuels. A typical method makes it possible to obtain biodiesel, a renewable fuel. Waste cooking oil (WCO) was trans esterified using heterogeneous catalysts to make biodiesel. The paper deals with the comparative study of the different biofuels available in the market and the optimum utilization of the resources for production with higher engine performance. This research paper studies the employability of biofuels in diesel engines in different operating conditions using different types of catalysts. The investigations show the three different types of fuels Ultra Low sulfur diesel, 30% by volume blend of Rapeseed Methyl Ester (RME), and 30% by volume blend of Hydrogenated Vegetable oil; test depicts the comparative properties of the fuel using three blends.

Introduction

Global demand for renewable fuels has increased as a result of the need to ensure sustainability and maintain a pollution-free environment. Global demand for renewable fuels has increased as a result of the need to ensure sustainability and maintain a pollution-free environment [1]. There is a need for additional fossil fuel substitutes due to the depletion of crude oil reserves, the issue of environmental degradation, the rise in demand for petroleum, supply instability, and the price of crude oil. [1-5]. Finding new alternative fuels that lessen our dependency on imported crude oil and promote sustainable environmental protection is urgently needed. Several fuels recently investigated are promising substitutes for the highly polluting ones currently in use. The alternative fuel with the greatest promise for use in traditional diesel engines is biodiesel. Long-chain fatty acid mono-alkyl esters are created from vegetable or animal oils and alcohol, either with or without the use of a catalyst. [5-9]

"Monoalkyl esters of long-chain fatty acids resulting from edible oils, non-edible oils, and waste oils," is how the American Society for Testing and Materials (ASTM) defines biodiesel (Yusuf). Technically speaking, it is the transesterification of vegetable or animal oils with alcohols, aided by an acid or base catalyst, at a particular reaction temperature. The end product is an alkyl ester of fatty acids.[11]. Biodiesels are divided into four generations based on the origins of their feedstock. The first generation is produced synthetically using food oils. The first generation

of biodiesels was made from the vegetative oils of soybean, canola, rapeseed, and palm plants (Binweel). Second-generation non-edible oils are made from plants like pongamia pinnata, jatropha curcas, and madhuca indica in India [12]. Waste oil from the third generation is utilised for frying and other things. The third generation of biodiesel, according to some academics, is made from microalgae. According to performed research, the fourth generation contains synthetic biology technology, which is still in its infancy, [12].

The procedure used for producing biodiesel is transesterification. With catalysis present, the chemical reaction between the oil and alcohol is reversible. A different alkyl group from alcohol replaces the oil ester's alkyl group during transesterification [14]. Methanol, ethanol, propanol, and butanol are suitable short-chain alcohols for this procedure. However, due to their accessibility and favourable physical and chemical properties, methanol and ethanol are frequently used [15]. Acid, base, or enzymatic catalysts can all be used to catalyse transesterification [16]. Triglycerides are transesterified with methanol to produce biodiesel. It is preferable to use an acidic or an alkaline catalyst to speed up the reaction. As a byproduct of this process, methyl esters and glycerol can be employed in the detergent business. [12]. Fatty Acid Methyl Esters (FAME), or biodiesels as they are chemically known, has a variety of physicochemical qualities depending on the feedstock and synthesis process. When choosing a fuel for diesel engines, consider factors

like high heating value, cetane number, quickly biodegradable components, and low carbon monoxide emissions [17].

The reports indicated that the choice of low-cost, environmentally benign, and sustainable feedstock is the most important of them. Currently, the main feedstock's used globally for the manufacturing of biodiesel include various edible oils such soybean oil, palm oil, rapeseed oil, and sunflower oil. However, they are distinguished by expensive feedstock and a dubious sustainability. Although non-edible vegetable oils, algal oils, animal fats, used vegetable oils, genetically modified plants, etc. are used as inexpensive feedstocks to make biodiesel cost-effective, more research is still needed to identify the feedstocks that meet the criteria for sustainability, low cost, and environmental friendliness. Creating efficient acidic

heterogeneous catalysts that would reduce the cost of producing biodiesel from low-cost, high-FFA non-edible oils is a challenge for the scientific community.(Athar)

Numerous researches have examined various engine designs using various biofuel feedstocks. However, it was discovered that the disadvantage of using biofuels prevented earlier researchers from discovering a fully functional alternative to fossil fuel. The current study attempts to answer the following research issues in light of this reality.

1. What problems have researchers run into when employing biofuel in engines?
2. What benefits are there from operating engines with various biofuels' feedstocks?
3. What are the different types of catalyst used in biodiesel and the effectiveness of using catalyst?

These review papers will analysis the following points:

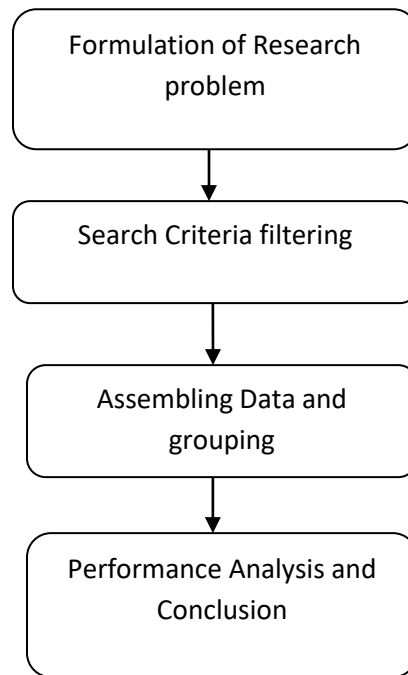


Fig.1 Flow Analysis used in Research

Different types of Biofuels for Biodiesel Production:

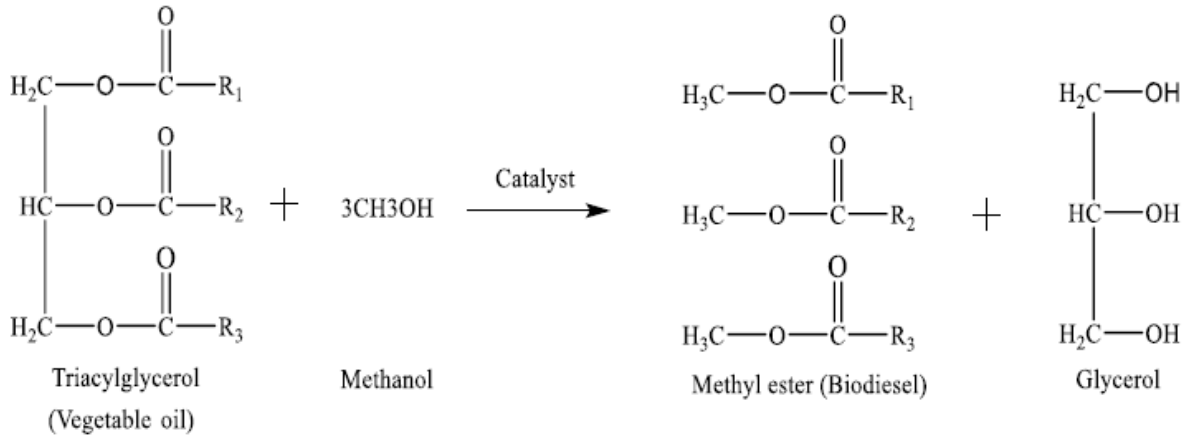
A procedure known as transesterification is used to create biodiesel from natural resources such as animal fats or vegetable oils. Although vegetable oil was used directly as fuel for compression ignition engines up until roughly 100 years ago,

this practice has a number of negative effects on engines. Vegetable oil has a low volatility, a high flash point, inadequate atomization with heavy smoke, carbon deposition, injector choke from excessive oil viscosity, etc. [19].

One mole of the oil triglycerides combines with three moles of alcohol to create one mole of

biodiesel. According to the reaction equation below, as shown in Figure [20], the product will be

3 moles of methyl esters + 1 mole of glycerol.



R₁,R₂and R₃ = Fatty acids of vegetable oil

Fig.2 Triacylglycerol transesterification reactions[12]

Vegetable oil is used to make biodiesel, which has inherent physical-chemical characteristics derived from the characteristics of the raw oil. According to a report, the raw material determines the majority of the physicochemical characteristics of synthesised biodiesel [17]. Other physicochemical characteristics of biodiesel came about as a result of production processes' handling and synthesizing steps. Performance of biodiesel fuel

is influenced by relevant physicochemical qualities that were synthesized. These physicochemical characteristics include things like acid value, suspended particles, and alcohol and glycerin content [12]. The physicochemical properties of 9 different oils are compared to find the emission characteristics of engine using different engine oils.

Biodiesel Sources	Density at 15 °C (Kg/m ³)	Kinematic Viscosity at 40 °C (mm ² /s)	Cloud Point (°C)	Pour Point (°C)	Flash Point (°C)	Heating Value (MJ/Kg)	Acid Value (mgKOH/g)	Cetane Number	Iodine Number (g I ₂ /100g)	References
Soybean	882	4.15	0	-3.2	160	39.76	0.18	58.1	11.7	[4], [25]–[28]
Coconut	867	3.1435	-1.6	-8.3	118.5	38.2	0.18	64.65	N/A	[4], [29], [30]
Mustard	888.9	5.53	16	-18	169.16	41.91	0.2	56	128	[4], [31]–[33]
Sunflower	869	4.10	1	-2	183	40.6	0.357	49	128.7	[4], [12], [25], [34], [35]
Palm	880	4.52	14.25	14.33	175	34.41	0.25	54.6	50.5	[4], [25], [36]–[38]
Sesame	867	4.580	-5	-9	180	40.1	0.32	56.32	80.32	[39]–[41]
Camelia	885	4.53	2.5	-6.3	150	52.2	0.36	52.8	146.5	[4], [42], [43]
Jatropha	880	4.80	4	2	175.5	40.79	0.48	57.1	95.75	[4], [25], [44],

Table-1 Comparison of physicochemical properties of biodiesels from 11 different vegetative oil sources.

Cetane Number:

It is defined as the ordinary cetane percentage by volume if biodiesel fuel combustion is conducted

in a standard engine under specified burning and operating conditions [24]. A high cetane number indicates that the biodiesel will burn quickly once it is ignited in the engine's combustion chamber. If

the cetane number is low, there may have been insufficient combustion, which would have resulted in increased exhaust emissions [21]. In order to provide a comparison, **fig.3** shows that

sunflower biodiesel has a cetane number of 49 and coconut biodiesel has a cetane number of 64.65. Other biodiesels have cetane numbers that are in the 50s.

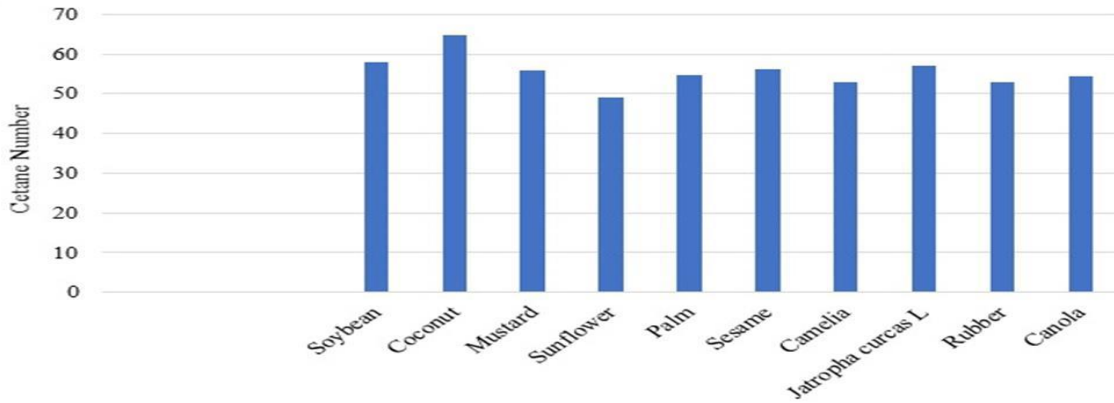


Fig. 4 Comparison of density at 15°C for biodiesels synthesized from different vegetative oils.

Heating Value:

If biodiesel fuel was burned completely under planned and controlled circumstances, it would release the heat content of the fuel within the unit quantity [24]. Heating value is thus a different way to express the energy content of biodiesel. Because unsaturated esters have a high volumetric energy and low mass energy, their saturation situation level in biodiesel affects their

heating value [26]. Biodiesel has a 10% lower energy content or heating value than fossil fuel diesel [11]. The biodiesels made from camelia, rubber, mustard, pond algae, Jatropha curcas L, and sunflower have the highest heating values (52.2, 42.372, 41.91, 40.8, 40.79, and 40.6 MJ/kg), while palm biodiesel has the lowest heating value (34.41 MJ/kg).

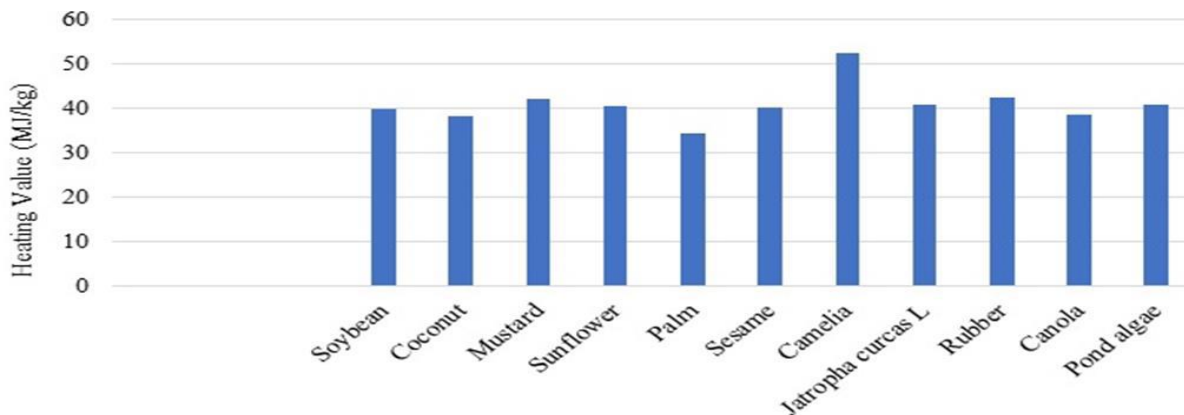


Fig.4 Comparison of kinematic viscosity at 40°C for biodiesels synthesized from different vegetative oils.

Flash Point:

The biodiesel fuel specimen ignites at the lowest temperature under normal air circumstances at this point [24]. The flash point of biodiesel is always higher than the flash point of diesel made from fossil fuels. The flash point of conventional diesel ranges from 55 to 65 °C. The reduced

volatility of biodiesel is the cause of the higher biodiesel flash point values. Because of this, biodiesel is thought to be safer in storage and transit instances [25]. The flash points of various biodiesel sources in this review range from 118.5 °C to 183 °C for coconut and rubber biodiesel, respectively

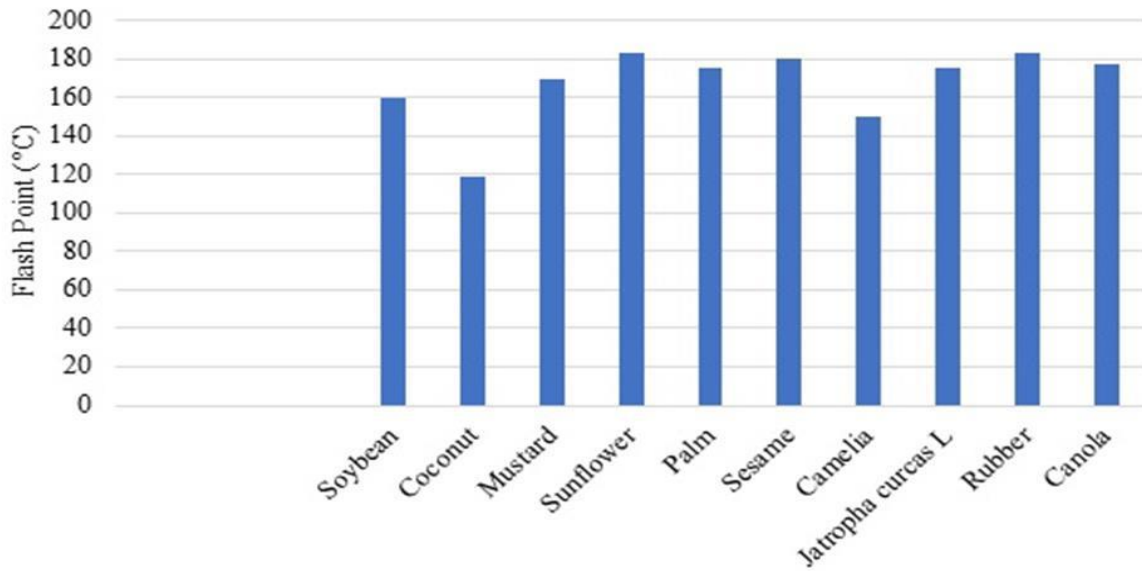


Fig.5 Comparison of flash point for biodiesels synthesized from different vegetative oils.

Cloud Point:

It is the temperature at which biodiesel begins to crystallise or form clouds of particles. Typically, fuel control at low temperatures is fixed using the cloud point. High cloud point values are seen as a bad characteristic for biodiesel since crystals can

form in typical weather. Such gasoline crystals cause issues with engines [23]. In cold climate regions, the highest cloud points for mustard and palm biodiesels—16°C and 14.25°C, respectively. In contrast, the lowest cloud points—5°C, -3.3°C, and -1.6°C—for sesame, canola, and coconut biodiesels, respectively, are the most desirable

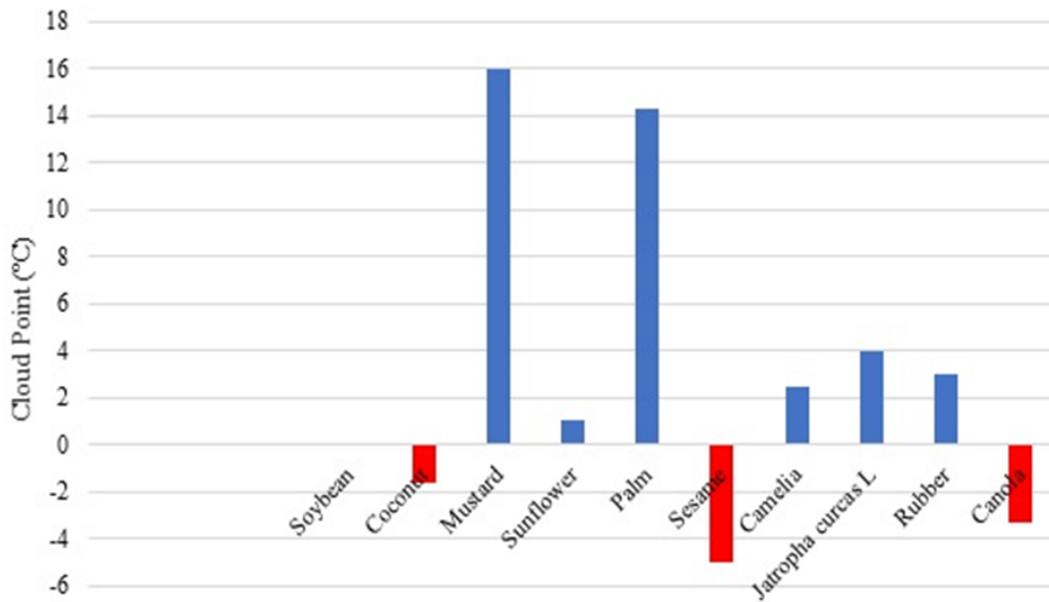


Fig. 6 Comparison of cloud point for biodiesels synthesized from different vegetative oils.

Biodiesel	Density (kg/m ³) @ 40 °C	Kinematic Viscosity (mm ² /s) @ 40 °C	Cetane Number	Heating Value (MJ/kg)	Iodine Value (g Iodine / 100 g oil)	Saponification Value (mg KOH / g oil)
Sunflower	841	4.87	47.8	39.5	136	193
Rubberseed	839	4.88	51	39.3	120	196
Jatropha	836	4.91	54	39.7	105	198.8
Cottonseed	837	4.95	52.1	39.4	113.2	202.7
Karanja	837	5.00	52	39.5	92	198
JT 80:20	834	5.04	59.2	39.6	88	197.5
JP 50:50	834	5.10	59	39.6	84	198
Neem	832	5.16	58.7	39.8	83.2	201
JT 50:50	835	5.21	62.2	39.9	83	214
SFCt 50:50	834	5.27	54.6	39.9	81.5	210
Mahua	830	5.33	61.4	40.5	80	187
Palm	830	5.39	64	41.0	59	205
JCt 50:50	829	5.45	58	40.2	69.2	215

Table-2 Biodiesel standards [4], [12], [19]–[23].

Biodiesel Production Using Catalyst

It is clear that using homogeneous catalysts for the synthesis of biodiesel has a number of issues, including high energy consumption, soap formation in high FFA oil, the challenge of catalyst separation, significant wastewater production during washing, and catalyst separation. As an alternative, heterogeneous catalysts might be used. Catalysts that are heterogeneous can be easily separated and used multiple times. Even unwanted saponification reactions can be prevented and used with high FFA oils. Because transesterification and esterification reactions can be carried out simultaneously with heterogeneous catalysts, production costs are reduced [27-29]. The three main types of solid heterogeneous catalysts are alkaline solids, acidic solids, and

bifunctional solids. The solid acidic catalyst can catalyze FFA present in the oil by the esterification reaction; the solid alkaline catalyst can catalyze the transesterification reaction; and the solid bifunctional solid catalyst (acid-base type) can catalyze simultaneously both the esterification and transesterification processes [34]. For the generation of biodiesel, research has been done on heterogeneous acid solid catalysts including sulfated zirconia-alumina (SZA), tungstated zirconia-alumina (WZA), and perfluorinated alkane sulfonic acid resin (Nafion-NR50) [32-33]. The transesterification and esterification processes can both be supported by a solid acid catalyst such as sulfated zirconia or tungstated zirconia[30-31].

Experimental Result

As per investigation of Fedrico et.al. on three different types of fuels as mentioned below:

- Ultra Low Sulfur Diesel (ULSD), compliant with EN590 (sul- 152 fur < 10 mg/kg) and hereafter referred to as “Diesel”; 153
- 30% by volume blend of Rapeseed Methyl Ester (RME) bio- 154 diesel with 70%

- diesel, hereafter referred to as “RME-B30”; 155
- 30% by volume blend of Hydrotreated Vegetable Oil (HVO) 156 with 70% diesel, hereafter referred to as “HVO-B30”

The key characteristics of the test fuels, and depict distillation curves and viscosity against temperature trends. It is evident right away 161, Compared to the 163 RME-

B30 blend, the 162 HVO-B30 blend has distillation and viscosity properties that are more similar to those of diesel fuel. On the other hand, RME-B30 has a distillation curve with a notable shift towards

fractions with higher boiling temperatures and greater viscosities, which may potentially 166 impair the fuel blend's spray and evaporation characteristics as per Federico et al.

Table 1
Main fuel properties.

Properties	Diesel (ULSD)	RME-B30	HVO-B30
Carbon content C, (w%) (ASTM D5291-10)	86.2	83.4	85.4
Hydrogen content H, (w%) (ASTM D5291-10)	13.5	13.2	14.1
Oxygen content O, (w%)	-	3.4	-
Total aromatics, (w%) (EN 12916:2006)	25.7	19.2	16.1
Sulfur content S, (mg/kg) (EN ISO 20846:2005)	<10	<10	<10
Stoichiometric ratio (A/F) _{st}	14.50	13.98	14.66
Net heating value, LHV (MJ/kg) (ASTM D240-09)	42.84	41.245	43.29
Cetane number (EN ISO 5165:2001)	51.2	52.8	60.7
Density at 15 °C (kg/m ³) (EN ISO 12185:1999)	837.5	853	812.2
Viscosity at 40 °C (mm ² /s) (EN ISO 3104:2000)	2.681	3.183	2.545
LHV/(A/F) _{st} (MJ/kg)	2.95	2.95	2.95
Oxidation stability (h) (EN 15751:2009)	-	9.9	27.4
Surface tension at 20 °C, (mN/m)	30.4	31.1	28
<i>Distillation temperatures</i>			
Initial boiling point (°C)	171.5	185	164.5
10% (°C)	202.4	223	204.3
50% (°C)	265.6	302.2	273.2
90% (°C)	335.8	340.2	317.2
Final boiling point (°C)	364.6	358.4	349.2

Table.3

According to a preliminary investigation of the behaviour of the injection system, the fuel properties have a complex effect on the mean injected volume and, consequently, the amount of energy that is supplied into the combustion chamber. In particular, the fuel density, viscosity, and bulk modulus can have a substantial impact on the transient behaviour of the injector for brief injection events. Significant disparities were found between RME-B30 and diesel fuel in terms of injected quantities, which were significantly reduced (from 18% to 6%) at low injection pressure. However, when injection pressure was increased, the variances began to diminish, nearing - 1% at 1200 bar. When HVO-B30 was used, the injected volume increased for moderate

injection pressure levels while it remained close to diesel for high rail pressure levels. For RME-B30, this led to a maximum 20% reduction in the introduced energy in the combustion chamber being seen at low injection pressures and brief injection events. The same analysis for HVO-B30 revealed an energy gap of roughly 8% to 2% at 1200 bar, 2% at 800 bar, and of approximately +4% to +2% at 400 bar, taking into account its differences to diesel in terms of density and LHV. In terms of engine tests, when the engine was fueled with the RME-B30, at full load operating circumstances, without any adjustments to the ECU calibration, a discernible decrease (4–5% on average) in the torque output could be seen.

When compared to diesel operation, smoke levels recorded under RME-B30 mix operations were significantly lower, demonstrating remarkable FSN reductions. Regarding the HVO-B30 mix, torque output levels comparable to diesel (with variances less than 1% on average) could be seen throughout practically the full speed range, although smoke emissions were generally still noticeably lower than diesel values.

On adding the nanoparticles result in the enhancing the emission characteristics of the diesel engine. As per the experimental result analysis of Mohsen et.al. to assess the impact of various characteristics, including engine performance parameters, physical properties, and pollutants by throttle parameters of nanoparticles at various engine speeds, combined fuel containing petrol, methanol, and additives was researched. The use of nanoparticles decreases the emission of pollutants, which increases the amount of heat required in the engine, according to the results of experimental tests, optimised modelling, and result analysis. By adding this additive, the engine's power and torque are also improved. In this test, the viscosity of each blend was reduced by 16.7%, while the octane index of the N-methanol-Fe₂O₃-Benz combination and the gasoline-TiO₂ compounds both increased by 10.9% and 9.9%, respectively. Both of the utilised nanoparticles appeared to have roughly the same effects, it can be said. TiO₂ had a bigger impact on motor power while Fe₂O₃ had a greater impact on torque. The results obtained are applicable to all internal combustion engines.

Result & Discussion

The usage of various biodiesel fuels can affect a diesel engine's performance characteristics. An environmentally friendly and sustainable substitute for petroleum diesel, biodiesel is often made from recycled cooking oil, animal fats, or vegetable oils. The following engine performance traits can be impacted by the use of various biodiesel fuels:

Energy Content: Depending on the production process and the feedstock utilised, the energy content of biodiesel can change. Because it directly influences the engine's power output and fuel consumption, the energy content of biodiesel is an important factor to take into account. An engine will typically operate better with biodiesel that has higher energy content.

Cetane Number: The fuel's ability to ignite in an engine is measured by its cetane number, which also serves as a gauge of the fuel's ignition quality. In comparison to petroleum diesel, biodiesel fuels often have higher cetane values, which can increase combustion efficiency and lower engine noise.

Lubricity: Compared to petroleum diesel, biodiesel often has higher lubricating qualities. This can give the engine's fuel injection system better lubrication, decreasing wear and extending the life of engine parts.

Viscosity: The viscosity of biodiesel fuels is often higher than that of petroleum diesel. The atomization of the fuel can be impacted by higher viscosity, which might result in worse combustion and could reduce engine performance. Modern diesel engines may run on a variety of fuel viscosities, but as long as they stay within specific bounds, biodiesel mixes are generally acceptable.

Cold Flow Properties: In colder climates, biodiesel may have worse cold flow characteristics compared to petroleum diesel. It might have a higher pour point and cloud point, which is the temperatures at which gasoline stops flowing and where crystals start to form. This may make it more difficult for the fuel to pass through fuel filters and injectors, which could cause problems starting and operating in cold weather.

Emissions: In comparison to petroleum diesel, combustion of biodiesel often results in lower amounts of several pollutants, including carbon monoxide, particulate matter, and unburned hydrocarbons. This may lead to better air quality and less negative environmental effects.

It is crucial to keep in mind that the specific performance traits of biodiesel might change based on the feedstock, production method, and quantity of blend with petroleum diesel. It is advised to check the recommendations of the engine manufacturer and confirm compatibility with the selected biodiesel fuel before using biodiesel.

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