# Review of Biodiesel's Performance and Emission in I.C. Engines with and without the Addition of Nano Additive

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## 1. Abstract:

Fossil fuel storage is depleting, and to maintain present levels of energy consumption, we must develop alternate fuels. Because of low energy levels, power generation and transportation that rely on fossil fuels will face challenges. Because of this circumstance, biodiesel is employed in I.C engines, however, it has significant drawbacks.

Biodiesel has a high density, a high fire point, a high fuel consumption, and a significant volume of nitrogen oxides. To avoid these drawbacks, additives are utilized to maintain international fuel standards.

This review paper includes studies on biodiesel production, the trans-esterification process, and a comparison of biodiesel with and without nano additions and their effects on performance and emissions.

**Key Words –** Biodiesel, Fuels, Oxides, Consumption, Emissions, Energy, and Additives.

## 2. Introduction:

Fuel prices are currently rising due to reduced storage levels of fossil fuels, and pollution from fossil fuels is increasing day by day, with emission standards becoming stricter. The needed fuels must have high energy density, low emission, low deposit formation, and be easy to start under ambient conditions. Biodiesel has a high density and is low in pollutants. It is composed of edible and inedible crops, seeds, and animal fats. Second-generation biodiesel is made entirely of non-edible seeds and crops. Plant oil, a less expensive non-edible vegetable oil, is the primary source of sustainable bioenergy.

Biofuels are directly used in diesel engines without requiring any modifications to existing engines, and biodiesel reduces CO, and HC but raises NOx percentage to prevent this problem. Pollution reduction and increased combustion efficiency.

**BIODIESEL:**

Because it is derived from vegetable oil and fatty acids, biodiesel is a green energy fuel. While biodiesel has approximately the same qualities as diesel fuel, it can be used in internal combustion engines. As fuel storages deplete and fuel prices rise, biodiesel, often known as next-generation green fuel, becomes more popular. Biodiesel is produced through the transesterification process, in which alcohol is introduced near oil under mild conditions in the presence of a base catalyst.

**TRANS-ESTERIFICATION PROCESS-**

There are different methods to convert oil to biodiesel as follows;

- Trans-esterification
- Blending
- Emulsion
- Pyrolysis

Trans-esterification processes are extensively utilized in the above approaches nowadays. The reaction of oil and fatty acids with alcohol to create esters and glycerol occurs during the trans-esterification process. Trans-esterification produces vegetable oil ester while increasing viscosity and volatility. Alcohol is mixed in the presence of a base catalyst under mild conditions. The kinematic viscosity and yield fluctuate as the reaction temperature changes. The temperature ranges from 55 to 85 degrees. The output of biodiesel reduces as the temperature rises. To make pure biodiesel, the bioproduct is washed with hot water to separate it from soap production and then tested according to ASTM standards to evaluate fuel purity.

**FUEL ADDITIVES-**

Biodiesel has some drawbacks, such as high density, high burn point, high fuel consumption, and a significant amount of nitrogen oxides; to mitigate this, additives are utilized. The additives will assist in reducing and maintaining emissions following environmental regulations, as well as improving efficiency.

Types of additives;

- Metal-based additives
- Oxygenated additives
- Cetane number improver additives
- Antioxidant additives
- Ignition promoter additives

- Lubricant additives

Most of the above metal base and lubricant additives are used.

**Nanoparticles additives-**

The addition of Nanopowder additives to biodiesel increases the quality of the fuel due to properties of nanoparticles such as high specific area, chemical properties, and so on. It improves engine efficiency and decreases emissions. When compared to bulk form, nanoparticles with smaller sizes have a higher specific volume ratio, surface area, and magnetic characteristics. Then metal and metal oxide improve efficiency and minimize pollutants. As a result, when used in I.C. engines, nanoparticles can act as both a catalyst and an energy carrier.

## 3. Significance:

Biodiesel is a renewable and environmentally friendly alternative to conventional diesel fuel, primarily derived from vegetable oils or animal fats. Its significance in internal combustion (I.C.) engines, both with and without the addition of nano additives, can be examined from various perspectives.

**Biodiesel in I.C. Engines:**

Renewable Resource- Biodiesel is produced from renewable resources, which makes it a sustainable alternative to fossil fuels. It helps reduce dependence on finite petroleum resources.

Greenhouse Gas Emissions- Biodiesel typically produces lower levels of greenhouse gas emissions compared to traditional diesel fuel. It can contribute to mitigating climate change by reducing the carbon footprint of transportation.

Biodegradability- Biodiesel is more biodegradable than conventional diesel fuel, reducing environmental impact in case of spills or leaks.

Engine Lubrication- Biodiesel has better lubricating properties than traditional diesel, which can enhance the longevity of engine components.

Energy Security- The production of biodiesel can contribute to energy security by diversifying fuel sources and reducing dependence on imported oil.

## 4. Literature Review:

A literature review is an overview of the previously published works on a topic. Either way, a literature review is supposed to provide the researcher and the audience with a general image of the existing knowledge on the topic under question. The following are selected researchers who carried out their work related to Biodiesel Performance and Emissions in I.C. engines with and without nano Additives. The literature presented below is taken from various journals like Science Direct, ResearchGate, etc. which are Scopus-indexed journals.

1. **Biodiesel without adding nano-additives:**

**Rakesh Kumar et. al. (2017)** experimentally determined the performance and emission characteristics of a single-cylinder direct injection diesel engine operated on diesel/ biodiesel blends (B20, B40, B60, B80, and B100). The result shows that the maximum Brake thermal efficiency (BTE) was obtained for the B20 blend which is 30.1% (more than diesel 27%). The BSFC for B20 was also similar to diesel fuel. The detailed analysis of the experimental result shows a significant decrease in carbon monoxide (CO), hydrochloric acid (HC), and smoke. The result of experiments shows that the use of biodiesel produced from argemone mexicana methyl ester seed oil in diesel engines is a possible solution to a problem associated with diesel fuel.**[1]**

**S. S. Sajane et. al. (2016)** studied the performance and emission characteristics of a Variable Compression Ratio (VCR) diesel engine fueled with biodiesel (Rapeseed Oil Methyl Ester-ROME) using EGR. Experiments are conducted on a single-cylinder, four-stroke diesel engine powered by a Variable Compression ratio with 0%, 5%, 10 %, and 15% EGR keeping the load constant (12kg). Various engine performance parameters such as Brake thermal efficiency; Specific Fuel Consumption, Mechanical efficiency, etc. were calculated from acquired data. The engine performance and efficiency obtained with biodiesel were less as compared to diesel which can be attributed to the lower calorific value of biodiesel. At CR-18, the performance and emission parameters for ROME are better when compared to another compression ratio. This indicates the feasibility of using ROME as an alternative fuel for diesel. With the application of EGR the NO emissions were considerably reduced. However, using EGR at high levels results in certain penalties. It increases CO and HC emissions and also affects the performance. **[2]**

**Singh et. al. (2014)** investigated the performance and emission characteristics of prepared three different types of cooking oil biodiesel blends namely B10%, B20%, and B30% at various compression ratios like 12, 14, and 16 on a compression ignition engine and important fuel properties like oxides of nitrogen, HC and CO were determined. The experimental results also showed that the smoke emissions were reduced for all biodiesel mixtures and hydrocarbon (HC) and NOx emissions of the B10% blend are the lowest among all. From all the results it was concluded that a B10% blend of waste cooking oil biodiesel acts as the best alternative fuel among all tested fuels at full load condition. **[3]**

**A. Tiwari et. al. (2018)** has studied research on Mexicana oil production and physiochemical properties. Also investigated the blends of Mexicana methyl ester which gives optimum results at various loads and Compression Ratios. From the study, it was concluded that the Physiochemical properties of Mexicana methyl ester are suitable for diesel engines. The flash point of Biodiesel is higher than diesel fuel hence it can be stored for a long time. The performance of blend B20 was found to be closer to that of diesel fuel. Emissions of CO2, HC, and CO are minimal at high loads and high CRs as compared to that of diesel fuel. **[4]**

**P. Achari & A. T. Autee (2017)** have reviewed the various properties, engine performance, emission characteristics, and combustion parameters experimentally carried out by various researchers. They summarized that the use of dual fuel blend improves properties like kinematic viscosity, specific gravity, surface tension, cetane number, flash, and fire point temperatures with an increase in concentration in the blends. **[5]**

**Mrunay Jadhav et. al. (2017)** has investigated new non-edible oil except Karanja, Jatropha, and Neem. Argemone Mexicana is a weed crop and its seeds oil biodiesel is extracted by transesterification process with methanol and tested on a single-cylinder, four-stroke diesel engine connected to an eddy current dynamometer fueled with argemone biodiesel and blended with diesel fuel under different load condition. The performance parameters like brake power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTHE), and emissions of CO and HC are compared with diesel fuel. They used 5%, 10%, 15%, 20%, 25%, 30% and 50% argemone Mexicana blends. From all the results they concluded that Maximum brake thermal efficiency noted at B25, B30, and B50 is higher than diesel, Mechanical efficiency is the same for B5, B10, B15, and B20 as compared with diesel fuel, HC, and CO emissions are less than diesel fuel. **[6].**

**S. Y. Nagwase et. al. (2019)** has reviewed the production and properties of Argemone Mexicana biodiesel and their comparison with diesel fuel. From the review, they concluded that Mexicana required only 1% manganese carbonate as a catalyst with alcohol for trans esterification Process and the use of Argemone Mexicana as an engine fuel has the potential to reduce exhaust emission since Mexicana oil has less than half of carbon dioxide emission than customary diesel.**[7]**

**2. Biodiesel with Nano-Additives and its Effect on Performance and Emissions:**

**M. Ghafoori *et. al*. (2015)** experimentally investigated the effects of Multi-Wall Carbon Nano Tubes (MWCNT) on a six-cylinder diesel engine, using waste vegetable oil methyl esters fuel produced through transesterification and blended with diesel fuel. The results of the design of an experimental set-up for swirling decaying flow investigations, alongside validation experiments. This result indicates that adding nanoparticles to biodiesel-diesel blended fuel can significantly reduce HC emissions. The addition of Nano-particles and Carbon Nanotubes enhances the combustion and causes for the hydrocarbon emission reduction. **[8]**

**S. Venkatesan, and P. Kadiresh, (2015)** presented an Experimental Investigation to determine the combustion, performance, and emissions characteristics of diesel engines using nano-aluminum oxide (n-

$Al_2O_3$) mixed diesel. The diesel fuel with and without n-$Al_2O_3$ additive was tested in a direct injection diesel engine at different load conditions and the results revealed a considerable enhancement in the brake thermal efficiency and substantial reduction in content of NOX and unburnt hydrocarbon (UBHC) at all the loads. **[9]**

**S. V. Reddy et al. (2017)** have reviewed the main results achieved up to now and are focused on the problem facing LHR engines with nano-coating operated on bio-diesel blends. They concluded that the engine emissions were improved in the LHR engine for all the fuels, NOx emission was increased due to increased combustion temperature, and the exhaust temperature was also increased in the LHR engine. **[10]**

**S. Karthikeyan *et al.* (2014)** studied the performance and emission characteristics of a diesel engine using alumina oxide nano additive, blended with grape seed. From the study they summarized that Flash Point and calorific value increase with the increase in $Al_2O_3$ Nano- additive, Heat release rate decreases, Brake thermal efficiency is increased, and Nox Reduced. **[11]**

**M. Ghanbari et. al. (2017)** have demonstrated that the Performance and emission characteristics of a CI engine using nanoparticle additives in biodiesel-diesel blends they observed by adding nano additives in biodiesel increases in torque and brake power, and decreases in emissions and CO and HC emissions Reduce and also reduced brake specific fuel consumption when added nano metal-based silver particles. **[12]**

**Prabhu L et al. (2014)** have investigated the performance and emission characteristics of a single-cylinder diesel engine using titanium oxide ($TiO_2$) nanoparticles as an additive in neat diesel and diesel-biodiesel blends. A 250ppm of titanium oxide nano-particle is blended with a 20% biodiesel-diesel blend (B20). The CO, HC, and smoke emissions were decreased while the NO emissions were increased marginally due to peak combustion temperature. **[13]**

**A. Joshi et al. (2018)** have studied the effect of cotton seed oil biodiesel with cerium oxide nanoparticles used along with diesel in various concentrations of B6 up to B36 and 35ppm of nano-particles in each of them. The experiment was carried out on a single-cylinder engine with a variable compression ratio. There is an increase in brake thermal efficiency at peak load with biodiesel, wherein B30 has a maximum value of 28.86%. The maximum exhaust gas temperature was noted for B30 with the value of 4050C at CR-16 and 389.050C. [**14]**

**H. Venkatesan et al. (2017)** studied the effect of nano additives on fuel properties, engine performance, and emission and concluded the addition of nano-additive performance increases and emission decreases, and also brake thermal efficiency increases. Nanoparticles like $Al_2O_3$, Al, CNT, and $CeO_2$ show good results as additives with diesel and biodiesel blends in all aspects. **[15]**

**H. Venu et al. (2017)** have experimentally investigated the performance and emission characteristics of biofuel blend (diesel (40 %)-biodiesel (40 %)-ethanol (20 %)) (denoted as BE). Comparative analysis was done for the addition of Diethyl ether (DEE) and alumina nanoparticles (Al2O3) at various concentrations. Experimental results indicate that, DEE addition in BE results in increased HC (Hydrocarbon), CO (Carbon monoxide), CO2 (Carbon dioxide), and BSFC (Brake specific fuel consumption) with lowered NOx (Oxides of nitrogen) and smoke emission. Al2O3 added in biodiesel increased NOx and smoke with lowered HC, CO, CO2, and BSFC, and Performance increases. **[16]**

**J. V. Naik & K. Kumar (2018)** has experimentally investigated the effect on performance and emission characteristics of C.I engine with Al2O3 and Cuo nano additives. By using Al2O3 emissions HC, CO, Nox were reduced up to 13.3% and Cuo using limited to 7.11 of HC, CO, and Nox emissions. Decreased BSFC for nano fuel Al2O3 more than Cuo. Better performance getting from Al2O3 nanofuel. **[17]**

**R. B. Nallamothu *et al.* (2019)** have studied the effects of the additive nanoparticles on the individual fuel properties, the engine performance and emissions are studied, and comparisons of the performance of the fuel with and without the additive are also presented. The reviews conclude that the uses of additives to the second generation of biodiesel are the best in improving combustion performance and emission reduction. [**18]**

**V. Praveena et al. (2018)** have studied the effect of Nano additives like Al2O3, CeO2, CuO, ZnO, Ag, CNT, MWCNT, etc. with biodiesel in I.C engines and concluded that the different additives and their effect on performance are increased and in emissions HC and CO reduced.**[19]**

**Rajayokkiam Manimaran et al. (2023)** have experimentally studied the novel green synthesized cerium oxide (CeO2) nano-additive that is used and produced from cerium nitrate hexahydrate using Azadirachta indica leaf extract to reduce NO. Subsequently, the presence of CeO2 is analyzed through different morphological studies. The CeO2 nano-additive is mixed with the 20% Trichosanthes cucumerina oil biodiesel emulsion in different proportions of 10, 20, and 30 ppm are used. From the experimental outcomes, TCB20 Emulsion+30 ppm CeO2 blend shows a significant reduction in hydrocarbon, carbon monoxide, smoke opacity, and NO emissions by 16.78, 38.30, 20.73 and 6.06%, respectively, when compared with standard diesel. Also, it was found that the TCB20 Emulsion+30 ppm CeO2 blend showed better engine performance with enhanced combustion characteristics.**[20]**

## 5. Concluding Remarks:

From the above Literature review, it has been found that;

- Production of biodiesel is very essential for reducing dependency on Petro-diesel fuel and for reducing the drawback of using these fuels for those countries which are importing fuels from another country by partially substituting because biodiesel can be used instead of diesel fuels.
- A nanoparticle additive plays a magnificent task in increasing the performance of the diesel engine, improving combustion, and reducing emissions.

## 6. Advantages & Limitations:

**Advantages:**

1. Renewable and Sustainable: Biodiesel is derived from renewable resources such as vegetable oils, animal fats, or used cooking oils.
2. Reduced Greenhouse Gas Emissions: Biodiesel has lower carbon dioxide ($CO_2$) emissions compared to conventional diesel fuel.
3. Biodegradability: Biodiesel is more biodegradable than traditional diesel fuel.
4. Improved Lubricity: Biodiesel has better lubricating properties than conventional diesel, leading to reduced wear on engine components such as fuel injectors and pumps.
5. Lower Sulfur Content: lowers $SO_2$ emissions.
6. Lower Particulate Matter Emissions.
7. A nanoparticle additive improves the combustion and reduces the emissions.

**Limitations:**

1. Cost: Biodiesel production can be more expensive than conventional diesel production.
2. Cold Weather Performance: Biodiesel can have poor cold flow properties.
3. Slightly higher $NO_x$ Emissions.

## 7. Conclusion:

1. Nano additions can improve efficiency and lower biodiesel emissions it does not require any engine modification.
2. It is clear from this literature review that nano additives play a significant role in lowering CO, $CO_2$, and HC emissions and improving I.C. engine performance, break thermal efficiency, and fuel efficiency.
3. Therefore, nano-additives have a bright future in diesel-biodiesel engines. Point out that adding nano additives to diesel-biodiesel fuel blends is considered a significant step towards enhancing environmental quality and safeguarding public health.

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