Influence of Nano-additive on the Performance of Diesel with Rape Seed Oil as Bio-diesel

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Abstract. Increased consumption of oil in a spectrum of uses currently poses a significant risk to worldwide level of exhaust emissions. Considering this problem requires considerable thought. As a result, the development of alternate fuels has become necessary. Bio-diesel is a renewable fuel made from mono - alkyl esters. This laboratory investigation contains a comparison analysis to ascertain the impact and operational features of nano fuel additives. The study focused on the mixing of rape seed oil based bio-diesel with silicon dioxide (SiO2), a nanoparticle based enhancer, in order to determine its influence on diesel burning IC engine’s performance. Various nano-mixture proportions were produced using nano-SiO2 particles with bio-diesel. The fuel used in the tests was bio-diesel mixer containing 25% of rape seed oil in diesel with 0.1%, 0.2%, and 0.3% SiO2 nanoparticles in bio-diesel. The output metrics such as brake power and exhaust emission levels were determined for the tested bio-diesels with different nano-SiO2 proportions. The bio-diesel with the 0.2% SiO2 nanoparticles yielded the better result in terms of brake power and emission characteristics of the engine comparing to the other blends.

Keywords: rape seed oil; bio-diesel; nano-SiO2; emission; brake power.

1. Introduction
The primary alternate fuel source is ascertained to be biofuels, which are renewable, natural, and ecologically benign as well. It is derived from a variety of natural items, including plants and their seeds, which would be a non-polluting, non-toxic, ecologically benign biofuel that degrades in the ground not causing environmental damage. Additionally, source emission is less and less polluting than diesel [1, 2]. Bio-diesel is a sustainable fuel source that can contribute to the reduction of carbon emissions. It contributes something to the increase in the world's ambient temperature, as plants extracts carbon dioxide from the atmosphere [3, 4]. Bio-diesels are mostly primarily utilized as
transportation fuel. Worldwide biodiesel output has significantly increased over the last few years. Biodiesel fuel may be utilized in normal diesel vehicles without requiring engine modifications.

Biodiesel is an ecologically responsible form of replenishable energy since it has superior lubricating qualities and produces much minimum pollution than current low diesel fuels [5, 6]. Additionally, bio-diesel decreases fuel supply system’s attrition and extend the reliability of direct injection apparatus that is dependent on low-pressure lubricant. Biodiesel produces greater burning, enhancing engine efficiency and somewhat compensating for petro-higher diesel's energy content. Global commercialization of oil products typically results in a dramatic rise in prices. The term "fossil fuels" refers to earthly fuels. These stockpiled hydrocarbons contain a finite amount of fuel and are thus irreversible. With our present petroleum resources and growing consumption levels, it is believed that they might run out sooner rather than later [7]. In certain parts of the globe, these limited sources of hydrocarbons are heavily concentrated, frequently resulting in interruption and price volatility. Even though globe's existing supplies appear enormous, increased use will make it difficult to replenish fossil fuels with a fresh form of fuel. Under chilly temperatures, bio-diesel performs significantly worse than diesel fuel; nonetheless, the mist and spill limits of bio-diesel are greater than those of diesel fuel [8].

The transportation industry is critical to the nation's growth and prosperity. Diesel vehicles have been commonly utilized to produce electricity and they have been used to drive autos, trains, boats, and agricultural equipment. Increased world's population and lifestyles will result in a fuel catastrophe [9, 10]. Given the significant growth in the economy for fuels and other petrochemical products, Country's reliance on fuel imports has predicted to expand by 95% in a couple of decades. As a result of previous oil crisis and depleting petroleum products, interest in alternative fuels, notably biofuel, is growing [11, 12]. There are several benefits to adopting biofuel as an alternative fuel, including its accessibility, environmental friendliness, possibility for use, biodegradability, and contributions towards longevity.

Biofuel may be made from a variety of plant oils, both culinary and non-consumable. Numerous scholars had advocated for the use of non-eatable oils as a more durable source of biofuel. They had found a number of non-eatable crops that could be utilized to make biofuel, including mungbean, henna, flax, groundnut, flaxseed, jatropha, subcontinent marijuana, horchow, tangerine, and latex kernel [13, 14]. Mahua oil based biofuel is used as a diesel substitute in a study, as its mineral content was nearly identical to those of other non-consumable oils [15]. Besides that, several papers in jojoba, moringa oleifera, and henna compounds are accessible. Mahua oil was obtained from the fruit of curcuma sativa, a hardwood plant native to semi-arid, equatorial, and subtropical regions [16]. Petroleum oil is widely accessible in Asia and its neighbours. In global country, it seems to have a potential yearly manufacturing capacity of around 200000 metric tonnes [17, 18]. The dryness output is approximately 60% of the grain weight. The bean kernel consists of around 49% fat. An extractor produces oil at a rate of roughly 35 percent [19, 20].

Moringa oil has been utilized straightly as biofuel in a cylinder; it results in lower atomization of fuel, detonation and the creation of soot deposits, engine clogging, and lubricating fluid infiltration, all of which are caused by the fuel's greater absolute viscosity. Numerous transformation procedures such as oil mixing, microscopic solubilization, busting, and esterification have been used to lower the viscous nature of moringa oil [21, 22]. Transesterification is just one of those processes that is commonly employed in commercial biofuel manufacturing. The use of biofuel in a diesel motor seems to have a number of drawbacks, including a modest reduction in diesel efficiency, a marginally greater specific gravity, lower fog and flow points, and increased NOX emissions. These drawbacks were mitigated by the use of methods like as gasoline additives, altered diesel, and hybridized diesel, which lead to lower pollution and improved performance characteristics [23, 24]. The adding of nanoparticles to biofuel improves the fuel's characteristics, increases burning rate, and decreases emission levels [25, 26]. Additionally, introducing nano-additives to diesel reduces particle emission, lowers the oxidizing temperatures, and increases NOX in exhaust [27, 28].
In the present work, the nano-SiO$_2$ particles of different concentration such as 0.1%, 0.2%, and 0.3% were used as the nano-additive in the bio-diesel containing rape seed oil in diesel. The proportion of rape seed oil in diesel was maintained as 25:75 based on previous works [2, 17]. The brake power as well as engine emission levels were studied for the varied proportion of nano-SiO$_2$ particles in the bio-diesel.

2. Preparation of bio-diesel

Mono-ester methyl lipid acids are the building blocks of biofuel. It was synthesized from triglycerides with the aid of transesterification process method. Rape seed oil comprise of 60% oleic, 20% linoleic and 4.5% palmitic acids, respectively. Transesterification is indeed a word that refers to the primary type of chemical reactions for which one ester is transformed to some other by the interchange of methyl group. The mechanism of transesterification is indeed an irreversible process that produces when the reagents have been combined. A stimulant, on the other hand, dramatically accelerates the steady state change [29, 30]. The triglycerides’ fatty acid atoms dissociate from their glycerol linkages and form new connection with the alcoholic molecules, culminating in glyceride as well a and fatty acid less esters.

Owing of rape seed oil’s lower acidity, the method of transesterification had been employed immediately and makes biofuel. The reacting vessel was loaded with 1000 ml of purified rape seed oil and boiled to 65°C for 15 minutes using a magnetic stirrer. Following that, a small volume of methyl alcohol and 2 ml of hydrogen sulphate was introduced to the rape seed oil. The process was then maintained at a constant agitation speed of 1400 rpm for 75 minutes [31, 32]. Once the process comes to a halt, pulp-like substance settled.

Succeeding the removal the pulp-like substance from the mixture, it was poured it into the beaker and stirred with the heating. Then, biodiesel's last rinsing procedure employed with the air circulation, the initial acidity of the oil was no longer required, as it was assumed that the biofuel was practically neutral.

Following water washing, the dehydrating process was used to eliminate any remaining moisture in the leftover oil. The oil was then placed in a beaker and boiled using a burner equipped with a magnetic stirrer to ensure that any remaining excess moisture in the fuel was removed. Finally, rape seed oil based bio-diesel was produced following the transesterification procedure. The nano-SiO$_2$ particles were commercially procured from Nanoshel. The heat conductance of the nano-SiO$_2$ is around 5 W/mK. The average particle size of the nanoparticles was measured as 15 nm.

| Sample Name | Diesel (%) | Rape seed oil (%) | Nano-SiO$_2$ particles (%) |
|-------------|------------|-------------------|---------------------------|
| DRS00       | 75         | 25                | 0                         |
| DRS01       | 75         | 25                | 0.1                       |
| DRS02       | 75         | 25                | 0.2                       |
| DRS03       | 75         | 25                | 0.3                       |

The premeasured 0.1%, 0.2%, and 0.3% of silicon dioxide nanoparticles have been disseminated in biodiesel blends using an ultrasonicator at a frequency level of 36 kHz for 40 minutes. In this way, the different proportions of SiO$_2$ nanoparticles in bio-diesel blend were prepared. The bio-diesel samples are presented in Table 1.

3. Experimental work

Tests were conducted on a water-cooled four-stroke single-cylinder diesel engine manufactured by Kirloskar. The photograph of the test rig is depicted in Figure 1. A constant speed of 1500 rev / min had been employed to test the engine. To give the braking force, the engine had been attached to the electric dynamometer arrangement. A calibrated burette and a stop clock had been utilized to determine the rate of fuel flow. Carbon monoxide (CO), hydro carbons (HC), and nitrogen oxide
(NOx) emissions had been examined using a high precision gas analyzing device. The test rig technical details are given in Table 2.

![Engine set-up for experimentation.](image)

**Figure 1.** Engine set-up for experimentation.

| Description                  | Details                          |
|------------------------------|----------------------------------|
| Engine brand                 | Kirloskar                        |
| Engine type                  | Four stroke, single cylinder     |
| Cooling system               | Water cooled                     |
| Bore and stroke              | 90 mm and 115 mm                 |
| Rated speed                  | 1500 rpm                         |
| Rated power                  | 5 kW                             |
| Compression ratio            | 18:1                             |

**Table 2. Technical details of the test rig.**

4. Results and discussion

![Brake power of the nano-SiO2 added bio-diesel.](image)

**Figure 2.** Brake power of the nano-SiO2 added bio-diesel.

Figure 2 shows the trend of brake power at different engine speeds for the bio-diesel mixture containing varying proportion of nano-SiO2 particles. The highest braking powers for bio-diesel blends DRS00, DRS01, DRS02, and DRS03 are 8.10 kW, 8.22 kW, 8.49 kW, and 8.17 kW, respectively, at
2400 rpm. Braking power of the engine was closely tied to the speed of the engine, since changes in engine crank speed has a significant influence on braking power of the engine. It is obvious that adding nano-SiO$_2$ particles to fuel mixtures greatly boosts the engine's braking power and overall power ratings. Moreover, SiO$_2$ nanoparticles' larger surface area contributed significantly to the combustion of bio-diesel mixers and improved the output power of the engine.

Figure 3 illustrates the engine's carbon monoxide emission levels. The CO emission results have been presented for the test fuels at 100% load condition and at a variety of operating speed levels. The highest emission was recorded at 1000 rpm for all bio-diesel blends. In comparison to conventional biodiesel without nanoparticles, the blends DRS01, DRS02, and DRS03 emitted lower CO. CO emission levels were reduced by 17.84%, 29.55%, and 9.67%, correspondingly, when DRS01, DRS02, and DRS03 had been used. DRS02 seemed to have the least CO emission values compared to almost all of the blends. It may be based on the argument that the SiO$_2$ nanoparticles increased the
reactive contact area, hence enhancing the complete of burning fuel and resulting in a reduction in CO production.

Figure 4 demonstrates the hydro carbon (HC) emission proportion of the engine emission. The HC emission of the engine has been plotted for the bio-diesels at 100% load condition and at a variety of operating speed levels. The highest HC emission level was documented at the speed of 1000 rpm, irrespective of the bio-diesel blends. The bio-diesel with the SiO\textsubscript{2} nanoparticles labeled as DRS01, DRS02, and DRS03 produced lesser HC compared to the plain bio-diesel. It can be clearly seen that the HC emission of the engine was dramatically reduced by 12.74%, 27.63%, and 13.08%, respectively, for DRS01, DRS02, and DRS03 fuel blends. Among all, DRS02 appeared to show the minimum HC emissions comparing to all other blends.

![Figure 5. NO\textsubscript{x} emission of the nano-SiO\textsubscript{2} added bio-diesel.](image)

The nitrogen oxide (NO\textsubscript{x}) emission data for the experimented fuel blends at the 100% loading and variable speed conditions is displayed in Figure 5. Peak NO\textsubscript{x} emission in the exhaust was noted for all the experimented bio-diesels at 3000 rpm, irrespective of the nanoparticle concentration. The mean increase in NO\textsubscript{x} levels for experimental fuels DRS01, DRS02, and DRS03 was observed as 12.56%, 7.85%, and 13.78%, respectively, as comparing to plain biodiesel. The inclusion of SiO\textsubscript{2} nanoparticles resulted in increment in NO\textsubscript{x} emission levels as compared to plain bio-diesel. The maximum NO\textsubscript{x} emissions were found for DRS03, whereas the least has been found for DRS02 for the fuel mixers having SiO\textsubscript{2} nanoparticles. Nevertheless, the nano-SiO\textsubscript{2} particle addition improved the rate of combustion.

5. Conclusion
The performance and emission characteristics of a diesel fuel burned IC engine were analyzed using a bio-diesel. Beforehand, the bio-diesel was prepared by blending 25% of rape seed oil in diesel. Further, the influence of various proportions of nano-SiO\textsubscript{2} particles in the bio-diesel was investigated after adding 0.1%, 0.2%, and 0.3% nano-SiO\textsubscript{2} particles in the bio-diesel, respectively. The results proved that the inclusion of nano-SiO\textsubscript{2} particles enhanced the brake power as well as emission characteristics of the diesel significantly in lower volume fractions. The bio-diesel with 0.2% nano-SiO\textsubscript{2} particles showed the maximum brake power of 8.49 kW, and least CO as well as HC emissions of 29.55%, 27.63%, respectively. The increment in nano-SiO\textsubscript{2} increased the NO\textsubscript{x} emissions. However, the nano-SiO\textsubscript{2} level of 0.2% in bio-diesel showcased moderately less NO\textsubscript{x} emissions. The best results were found with the nano-SiO\textsubscript{2} particle fraction of 0.2% in bio-diesel blend.
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