A review of the potential use of Biodiesel from Sesame oil

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Abstract

Need for renewable energy is gradually rising as a result of the rapid population expansion and worldwide economic development. Another reason is that there is limited fossil gas supply, which results in uneven supply across the region. Additionally, social perspectives, electrical regulations, and technical preferences are always changing. As a consequence, renewable energy sources are now being seen as viable alternatives to fossil fuels. Nevertheless, methyl ester, a liquid fuel made from local foods, is widely used in many countries, despite the fact that it is now blended up to 20% with petroleum fuels. Due to its oxidative balances and detrimental cold float properties, biodiesel industrialization has recently become a major mess. Vegetable oils are also combined in the right proportion before transesterification to provide biodiesel with the required qualities. Sesame oil, with its unique antioxidants and preservatives, stands out among vegetable oils for its enhanced rancidity resistance and exceptional cold flow properties, contributing to improved oxidative stability. To augment both cold flow and oxidative stability characteristics, sesame seed oil serves as a reliable foundation for blending with other prevalent oils. This research investigates the overall efficiency and emission properties of biodiesel mixtures formulated with artificial sesame oil, designed for use in internal combustion engines.

Keywords: Bio-diesel: Transesterification: CI Engine: Sesame: Emissions

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Introduction:

The social and economic growth of a country is largely influenced by its access to power. Renewable energy sources are available in India, including hydro, wind, and biodecomposition. The region encompasses eight of the top ten globally recognized natural gas reserves, while only accounting for three of the top ten proven crude oil deposits, amassing a total of 763.48 million metric tons [1]. Indian oil consumption constitutes approximately 5.3 percent of the global total, as per the latest data available, with Asia-Pacific accounting for 36.1 percent [2]. India's contemporary agricultural and transportation infrastructure are heavily dependent on fuels with a high petroleum content. Diesel fuel is widely recognized and extensively employed in a multitude of applications, encompassing locomotives, turbines, and mining equipment, among a plethora of others [3-4]. Fuel emissions have consistently posed a threat to the ecosystem and the atmosphere's ability to breathe. Environmental considerations and the long-term availability of resources are crucial factors that encourage the exploration of alternative solutions [5]. Consequently, edible oil, commonly referred to as biodiesel, is being examined as a viable alternative for the development of sustainable and renewable energy sources. Researchers from across the globe have conducted extensive investigations and discovered that biodiesel exhibits numerous properties akin to traditional diesel [6-7]. Because of it, these alternative fuels are better than diesel fuel because they are cheaper and better for the environment [8-9]. There have been studies showing the ability to generate bio-diesel from various vegetable oils. According to studies on its performance, peak cylinder pressure, and emission characteristic of Neem based bio-diesel was found to be promising [10-11].

Characteristics of biodiesel:

The oil produced by a simple chemical process utilizing the domestic and vegetable waste oil as well as those produced by waste animal fat that is safe to eat or not, microbial oils, algal oils, & vegetable oil, may be utilized for the generation of bio-diesel [12-16]. The different factors affecting the bio-diesel manufacturing include the accessibility of nearby lipid feedstock, the regional climate, geographic location, etc. Examples include soy oil from the United States; Jatropha oil originating from “India and Southeast Asia”; coconut oil sourced from the “Philippines”; rapeseed and sunflower oil hailing from “Europe”; and palm oil produced in “Malaysia and Thailand”. Few common feedstocks that are used for biodiesel production are palm, canola, sunflower, and rapeseed oils [12, 15, 17-19].In the table below, we list some of the most important things about it that make it good for mixing with biodiesel:

Attributes	Diesel	Sesame oil
Heating value(kj/kg)	42880	39350
Density	0.815	0.913
Viscosity	4.3 @	35.5@ 38
Cetane no.	47	40.2
Flash point	58	260
Sulphur	<0.01	0.01
Carbon residue	<0.35	0.25

Transesterification of Sesame oil:

Sesame seed oil may be used in a diesel engine either independently or in combination with other fuels. But sesame seed oil's is highly viscous and it is one main concern before utilizing it. Because of the high amounts of fatty acids coupled with good viscosity oil, many problems with CI engine have been reported. Some of these issues include blocked fuel hoses and filtration systems, insufficient fuel atomization, clogged injectors, piston ring corrosion, gum development as a result of oxidation while being stored, and a significant amount of carbon buildup in the various engine components. It results from thickening, incomplete combustion with insufficient oxygen, and mortification of the lubricant [20]. All of these issues are only brought on by the direct use of virgin oil, and thus they may be partially resolved by turning it into biodiesel. According to Ma and Hanna's (1999) study, there are four distinct techniques can be employed to transform unrefined sesame seed oil into biodiesel, subsequently serving as an appropriate fuel alternative for diesel engines. These procedures include transesterification, micro amalgamation, heat-assisted chemical breakdown, and direct application and mixing with raw diesel. The oil's viscosity may be lowered by mixing the unrefined sesame seed oil with crude diesel oil and subsequently, the blend is emulsified using a solvent, which may include methanol, ethanol, or 1-butanol. In spite of it the problem stays there which are due to carbon builds up and lubricating oil breaks down. Instead of biodiesel, the majority of the time pyrolysis, which is just the chemical process of breaking down with heat, is used to make bio-gasoline. The transesterification process stands out as the most effective technique for transforming unrefined sesame seed oil to bio-diesel, which will ultimately result in improved engine staging [21]. During transesterification, triglyceride (fat or oil) and alcohol mix chemically to produce esters and glycerol. This catalyst-assisted synthesis converts triglycerides into fatty acids and mono-alkyl esters (biodiesel), with alcohol produced as a byproduct. Employing a catalyst during the transesterification procedure not only accelerates the reaction rate but also improves the biodiesel yield obtained from the process. However, amount of catalyst that must be used is contingent on a variety of different elements. The oil variety, the amount of free fatty acids, and the presence of moisture within the oil are some factors that could potentially impact the process [22]. During the transesterification procedure, alkaline catalysts like “potassium hydroxide (KOH)”, “sodium hydroxide (NaOH)”, carbonates, and sodium and potassium alkoxides such as sodium methoxide are among the potential examples of the several kinds of alkali stimulants that may be utilised. A few instances of acids employed as catalysts encompass hydrochloric acid, sulphuric acid, and sulphonic acid. Biocatalysts based on lipases are a promising area of research. The transesterification process catalyzed by alkaline substances is considerably more rapid compared to the one facilitated by basic catalysts. For this reason, biodiesel production often employs the alkaline transesterification method [21]. Triglycerides can undergo a transformation into fatty acid monoalkyl esters and glycerol through a tripartite procedure.

When transesterifying oil with an estimated free fatty acid concentration of less than 1%, homogenized alkali base catalyst have been found to be maximum responsive. The formation of soap during transesterification is undesirable, esterification is used to suppress this side effect and boost yields [22]. Sarve et al. (2015) conducted research on synthesis of bio-diesel using sesame oil by employing wide range of various stimulants ($Ba(OH)_2$). In the research, several stimulants were used. He used transesterification with the assistance of ultrasound operating at a frequency of 20kHz, which resulted in an increased biodiesel production that was 98.6% more effective. As a consequence of this, ultrasonic processes may cut down on both time and temperature while simultaneously increasing output [23].

Optimization of sesame seed oil methyl ester:

In spite of the enormous amount of research that has been carried out, the method of transesterification still has to be perfected. Optimization is required to get the highest possible yield while maintaining the highest possible purity. The usual approach to optimization takes a significant amount of time. Due to the extensive number of examinations involved, it is both time-consuming and expensive [24]. Traditional experiments are often carried out as part of the optimization process in order to determine, via a process of trial and error, which variables in the technique provide the most value. The use of “response surface methodology (RSM)”, is done with intention of making the process more effective. It is often used to improve processes and find out how input variables and output variables are related [25]. RSM is often used to improve answers or choose the best working conditions so that the best possible output result can be reached [26]. The researchers, Dawodu et al. (2014), used a method known as “central composite design (CCD)” to figure out the highly effective approach for optimising the process variables for sesame (“Sesamum indicum L.”) oil transesterification. The maximum yield of 87.80 percent sesame seed oil methyl ester was projected to be attained at a reaction temperature of 50 degrees Celsius for a duration of 30 minutes, employing 0.75 percent sodium methoxide as a catalyst, and a molar ratio of 6:1 between methanol and oil [27]. Research was carried out by Sarve et al. (2015) with the purpose of improving the bio-diesel synthesis efficiency to enhance output. The best catalyst concentration, reaction temperature, and methanol-to-oil molar ratio were established in order to achieve this goal. RSM and “artificial neural networks (ANN)” were two optimisation tools he employed. Under these optimum process parameters, yield conversion reached 98.6% in a response time of 40.30 minutes at a reaction temperature of 31.92 degrees Celsius, a methanol to oil molar ratio of 6.69:1, while stimulant content of 1.79 percent (variable). Using sensitivity analysis, he looked at how each independent variable affected the final result. Through a sensitivity analysis, he determined the catalyst concentration had the biggest impact on the yield of fatty acid methyl ester. It was plainly clear, based on the outcomes of his experiment, that ANN had a lower value of correlation coefficient, standard error of prediction, root mean square error, and relative percent depression than RSM did. Because of this, the artificial neural network is the most accurate prediction model for both the presence of methyl ester and fatty acids [23].

Biodiesel standards:

For diesel engines, biodiesel is regarded to be substitute to crude diesel. The method of transesterification is the one that is used in synthesis of bio-diesel using eatable and non-eatable vegetables oil [20], as specified by the standards that were set by the “American Society for Testing and Materials (ASTM) D6751” and “EN14214”. According to the findings of the vast majority of studies, it may be attributed that a higher flash point than diesel may be responsible for its high level of fire resistance. The viscosity of biodiesel, which has a golden amber color and is similar to crude diesel, is around the same [28-29]. EN14214, which originates from the European Union, and ASTM D6751, which originates from the United States, are the two international organizations that are responsible for establishing the standards for the manufacturing of biodiesel. The minimal criteria that must be satisfied by all biodiesel manufacturers around the world were established by these two organizations [30].Variations of biodiesel with a low percentage, such as B7 or B10, are used in a number of locations across the world, including Malaysia. After Indonesia the Malaysia is major producer of palm oil in the world, so the nation planned to start using biodiesel manufactured from palm oil with a B10 standard in 2019. Malaysia holds the distinction of being the foremost nation globally to devise and implement evaluation standards for palm oil methyl ester biodiesel. The majority of the standard values come from the "ASTM D6751" and "EN14214" standards, which are the main sources for these values. "American Society for Testing and Materials ASTM D6751", is the organisation that was responsible for establishing a standard for biodiesel. Any kind of biodiesel must first be able to demonstrate that it satisfies these standards and has attributes that fit within the boundaries and ranges that have been outlined above before it can be used on its own or combined with diesel. To ensure the quality of biodiesel, the European standard EN 14214 establishes both upper and lower limits for a number of variables [32]. In order for biodiesel to be marketed either as an unblended biofuel or as a blending commodity for diesel fuel, it must first meet upper & lower limits of the variables that are required by the normal. The EN 14214 standard determines the maximum amount of a number of different components that may be present in biodiesel at one time. This is done to guarantee that the quality of the biodiesel produced is high [33].

Engine Performances and Emissions utilizing Sesame Oil:

According to the results of studies conducted by scientists from all over the world, switching from diesel to biodiesel will result in a drop in hydrocarbon emissions, a clearing of the air, and a lower output of carbon monoxide. More than 11% of biodiesel is composed of oxygen, which not only improves combustion quality but also facilitates the conversion of carbon monoxide to carbon dioxide [34]. When fuel is burned completely, the quantities of CO and other particle pollutants that are produced are reduced. When compared to crude diesel, SSO methyl ester produces higher levels of CO emissions but lower levels of smoke, HC, and NOx. A variety of factors affect the amount of nitrogen oxides produced, including the temperature of the combustion in the cylinder, the rate of the reaction, and the availability of oxygen in the air [35]. The amount of nitrogen oxide (NOx) emissions that are reduced is greatest with sesame oil bio-diesel. Utilizing sesame biodiesel with a low carbon number (CN) allows for the in-cylinder combustion temperature to be maintained at a minimum, which in turn decreases the nitrous oxide emission.

The BSFC of biodiesel-diesel blends, excluding those formulated with linseed and jatropha methyl ester, exceeds that of conventional diesel fuel. This is not the case with crude diesel. Because of biodiesel's high density and viscosity, a greater quantity of fuel is fed into the combustion process, leading to a higher BSFC. The connection between BTE and BSFC is antagonistic. Both maize and sesame biodiesel are effective in lowering NOx levels in blended form. Engine efficiency and emissions parameters while using sesame bio-diesel have only been studied seldom [36, 37]. Sesame biodiesel might be a workable alternative for decreasing nitrogen oxide emissions if it is blended with an additional feedstock that is acceptable for the purpose.

H. Rahmen et al. (2007) used a mahua oil/diesel oil blend in an experiment using a one-cylinder, 4-stroke, CI engine. The BSFC rises when there is more mahua oil present and reaches its peak for B100. However, it falls when there is a greater demand on the system, which is true for all fuels. When the engine is under increased load, its heat loss is negligible. Because of this, as the weight goes up, the amount of fuel that is needed goes down. The average BSFC for the blend was greater in comparison to the consumption of pure high-speed diesel by 4.3 percent, 18.6 percent, 19.6 percent, 31.7 percent, and 41.4 percent, respectively. This was the case for every 20% increase in the blending of biodiesel into diesel. In the majority of instances, the brake thermal efficiency (BTE) experienced a decrease as the proportion of B100 within the blends was elevated, resulting in higher values than that of standard diesel fuel. In comparison to diesel, which has a maximum BTE of 24 percent, the maximum BTE for B20 and B40 is 25 and 24 percent, respectively. It may be due to B20 containing higher oxygen than clean diesel, which leads to more vigorous burning. There was a 10.12 percent decrease in break thermal efficiency for B100 compared to high-speed diesel [38]. Diesel fuel and sesame oil were studied by Sehmus Altuna and his team as potential alternative fuels for a direct-injection diesel engine. Both of the fuels were used in equal amounts. The efficacy of a diesel engine's engine, as well as the exhaust pollutants produced by a diesel engine, were analysed and compared in this research project using regular diesel fuel. The experiment showed that when sesame oil was mixed with diesel fuel, the engine generated power and torque that were almost identical to those produced by diesel fuel alone. The levels of exhaust pollutants, on the other hand, were lower than those produced by diesel fuel. This led to the finding that a blend of diesel fuel and sesame oil can be utilized effectively in a diesel engine as an alternative fuel without requiring any modifications to the engine itself and that its emission characteristics rendered it an acceptable fuel for the environment. This was accomplished without the engine requiring any modifications [39].

According to the conclusions that Banapurmatha and colleagues came up with, biodiesel may be used either in its unblended form or by blending it with diesel in order to produce a range of blends. Either way, it is possible to utilise it. Due to the fact that it has characteristics that are comparable to those of mineral diesel, it is appropriate for use in compression ignition engines and requires very little to no modification of the engine in order to do so. Experiments have been carried out by the author in order to study the performance characteristics of engines and the harmful emissions that are produced by them. When he compared his findings, he discovered that out of the three distinct esters of edible oil, the methyl ester of sesame seed oil has the best performance for the engine, and it also enhances the thermal efficiency of the brakes. In addition, there was an improvement in the emission characteristics, as there was a low emission of HC, CO, and NOx [40]. Dinesha et al. [41] looked at using used cooking oil and sesame oil as potential feedstocks for their biofuel research. He used a combination of fuel made from vegetable oil and kerosene in the wick stove that he was experimenting with. The rate of fuel consumption, the thermal efficiency of the brakes, and the structure of the flame were all subjects of his investigations. Also investigated were emission characteristics such as NOX, CO, and CO_2 levels. His findings indicated that using kerosene oil led to improved performance. But the emissions caused by using kerosene oil were the worst. In addition to this, he used an ester made from vegetable oil that was 50% of the total, which led to a reduction in the amount of emissions produced while having a little detrimental effect on the overall performance of the engine. However, this finding demonstrated that the mixture would be quite close to being optimal.

Enweremadu et al. [42] performed study for determining the effect of utilising UCO bio-diesel on engine performance, the burning of fuel, and the pollutants produced. When compared to diesel, the outcomes that can be achieved with UCO biodiesel and the different combinations that it may be made with do not compare well to those that can be achieved with diesel. Use of UCO bio-diesel produced a higher quantity of NO_X emissions. Conversely, there was merely a slight decrease in the quantity of uncombusted hydrocarbons emitted into the atmosphere. Utilizing biodiesel and its mixtures resulted in a decline in brake thermal efficiency, along with a minor rise in brake specific fuel consumption, as discovered by Qi et al. [43]. Biodiesel and its blend show a significant decrease in the amount of CO & smoke emissions produced by the engine under extreme loads. Hydrocarbon (HC) content did not noticeably change in any of the tested fuels (HC). Nitrogen oxide (NOx) levels were somewhat elevated in biodiesel and its mixes. In terms of combustion, biodiesel and its mixes performed similarly to diesel fuel. Concerning performance parameters and emissions, soybean-based transesterified crude oil could potentially serve as a partial substitute for fossil diesel in a wide range of applications without requiring alterations to current engines.

Ekem Buyukkaya [44] carried out a study examining the efficiency, emissions, and combustion of a diesel engine with different proportions of rapeseed oil blended into the diesel fuel. The rapeseed oil content ranged from 5% to 70%. Findings indicated that biodiesel exhibited up to 60% reduced smoke opacity and up to 11% increased brake specific fuel consumption in comparison to diesel fuel. As compared to diesel, carbon monoxide emissions in the B5 category were reduced by 9%, while emissions in the B100 category were reduced by 32%. At rated power, the brake-specific fuel consumption of biodiesel is 8.5% higher than that of diesel fuel, and when assessed at peak torque, it exceeds diesel fuel by 8%. It took much less time for the rapeseed oil and its mixture to ignite compared to the time it would have taken for traditional diesel. Combustion properties of rapeseed oil and its diesel blend were found to be similar to those of traditional diesel. The researchers Raman et al. [45] investigate whether or not pine oil might be used as a source of energy. Compared to diesel, this alternative fuel exhibited reduced viscosity, boiling temperature, and flash point. Diesel had a higher value for each of these characteristics. Since pine oil has the same calorific value as diesel, it is feasible to use it without first putting it through the process of transesterification. This can be attributed to the identical viscosity of diesel and pine oil. At full load, the emission of CO, HC, as well as smoke decreased by sixty-five percent, seventy percent, and seventy percent, respectively, when using a diesel blend containing twenty-five percent, fifty percent, or seventy-five percent pine oil, or one hundred percent (Pinus sylvestris) pine oil. The greatest amount of heat released and the maximum specific fuel consumption both experienced rises of five and twenty-five percent, respectively, when compared to the previous values. Nitrogen oxide emissions, on the other hand, were found to be much greater than diesel emissions [45].

During their experiment, Pali Rosha and colleagues [46] used a compressed ignition engine with a predetermined compression ratio in conjunction with a mixture of biodiesel that included 20% biodiesel. Researchers were able to evaluate the impact of varied ratio of compressions (16:1, 17:1, and 18:1) on a variety of engine characteristics by combining palm bio-diesel at a concentration of 20 percent in an engine with compressed ignition. This allowed the researchers to evaluate the impact of the variable compression ratios on the engine. When the compression ratio of the engine was increased from 16:1 to 18:1, there was a decrease in the ignition delay; however, there was also an increase in the maximum cylinder pressure as well as the thermal efficiency of the brakes. There has been a 35.7 percent drop in hydrocarbon emissions as well as a 41.0 percent decrease in carbon monoxide emissions, and there has been a 41.0 percent decrease in smoke opacity. On the other hand, emissions of nitrogen oxide have grown by a factor of 41.1 percent. The findings of these experiments indicate that there is a good chance that biodiesel will show itself to be a viable alternative to regular diesel fuel in the not-too-distant future. It is also essential to highlight the fact that the usual percentage of biodiesel blends in the industry is 20 percent. As a direct result of this, the purpose of this review is to investigate the viability of using tertiary-refined sesame seed oil as a source of biodiesel. Throughout the course of this inquiry, a biodiesel that was produced from sesame seed oil will be used so that its overall performance as well as its emission characteristics can be analysed. To have a better knowledge of the combustion process, one of the factors that may be modified in an engine that has the capability of changing its own compression ratio on itself.

Conclusions:

The last decade was appealing for the use of biodiesel as a possible solution to the twin concerns of lowering pollution and challenging the monopoly that the natural crude oil sector has on the production of energy. Both of these issues have been a source of concern in recent years. It is possible to convert a standard diesel engine to operate on biodiesel without any further modifications being necessary. Researchers have looked at a wide variety of potential feedstocks in order to produce biodiesel, and some of these researchers have even been successful in making biodiesel ready for usage in commercial settings. Since it does not have the characteristics of excellent low temperature flow property as well as instability to oxidation, the industrial production of biodiesel presents a significant problem for the industry. This is an essential obstacle. In the context of CI engine, the study emphasizes on the performance and emissions characteristic of sesame seed oil that is being produced synthetically with intentions of use in such engines. During the manufacturing of biodiesel, sesame seed oil is blended with various other edible oils in order to increase the final product's ability to withstand oxidation and maintain its fluidity at low temperatures. Since it has unique physicochemical qualities in contrast to those possessed by other raw materials that are used in the manufacture of staples, sesame seed oil is an excellent candidate for use as a staple in the manufacture of biodiesel. A high level of resistance to rancidity is possessed by certain of them. Because of the significant degree of unsaturation that SSO contains, one would expect it to have poor oxidation stability. Since sesame seed oil does not contain any sulphur or ambrosial compounds, it does not produce the potentially harmful gas SO_2 during the refining process. The mixture of up to 20% may increase not only the performance of the engine but also the quantity of exhaust pollutants it produces. Later on, however, the blending was increased since the high specific fuel consumption, injector blockage, and engine deposit were causing problems. In order to optimise the performance of diesel engines, it is essential to carry out in-depth research on the function played by sesame seed oil methyl ester during engine operation. This will allow for the most effective use of the engine's resources. It is essential to carry out research on the emission and performance characteristics of engines that make use of sesame methyl ester. In addition to this, the lubricity properties of sesame methyl ester should be examined, as should its biocompatibility behaviour. Even though a considerable quantity of research has been carried out, the manufacturing procedure still needs a great deal of technological innovation in order to maintain its position as a contender in the global market.

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