

Performance, Combustion and Emission Characteristics of Diesel Engines Powered by Fish Oil and Diesel Blends

S. Jacob^{a,f}, R. Sabarish^b, R. Rajasekar^c, R.J. Golden Renjith Nimal^d and A. Sangeet Sahaya Jeyangel^e

^aDept. of Automobile Engg., Vels Inst. Sci., Tech. and Adv. Studies (VISTAS), Chennai, Tamil Nadu, India

^bDept. of Mech. Engg., Bharath Inst. Higher Edu. and Research, Chennai, Tamil Nadu, India

^cDept. of Automobile Engg., Bharath Inst. Higher Edu. and Research, Chennai, Tamil Nadu, India

^dDept. of Mech. Engg., Jai Shriram Engg. College, Tirupur, Tamil Nadu, India

^eDept. of Automobile Engg., Madras Inst. Tech. Campus, Anna University, Chennai, Tamil Nadu, India

^fCorresponding Author, Email: jacobthermal@gmail.com

ABSTRACT:

The worldwide fuel crises that occurred in the 1970s brought the issue of many countries' susceptibility to oil embargoes and shortages to the forefront of public consciousness. Blends of fish oil and diesel fuel were researched and it was found that they were technically feasible to use in vehicles. The development of alternative fuel sources received a significant amount of attention. As a direct consequence of this, the use of alternative fuels as a means of satisfying these prerequisites has attracted a lot of interest. Because of this, there has been a resurgence of interest in the mixtures of fish oil and diesel, with a particular focus on its potential use as an alternative fuel in diesel engines. A lot of considerations need to be taken into account while looking into alternative fuels that could be used in diesel engines. The goal of this study is to provide a review of these difficulties, paying special attention to concerns pertaining to distribution and safety. In the experiment, different proportions and evolutions of critical qualities like flash point, fire point, viscosity and calorific value are analyzed and the results are tabulated and graphs are made, respectively. According to the findings of this investigation, the most effective ratio was found to be 80% diesel and 20% fish oil.

KEYWORDS:

Diesel; Performance; Combustion; Emission; Fish oil

CITATION:

S. Jacob, R. Sabarish, R. Rajasekar, R.J.G.R. Nimal and A.S.S. Jeyangel. 2024. Performance, Combustion and Emission Characteristics of Diesel Engines Powered by Fish Oil and Diesel Blends, *Int. J. Vehicle Structures & Systems*, 16(3), 382-389. doi:10.4273/ijvss.16.3.12.

1. Introduction

Research into alternative fuels for internal combustion engines has been boosted as a result of growing concerns about the traditional petroleum supplies diminishing availability. The rapid rise in industrialization and motorization that has occurred all over the world has caused a sharp increase in the demand for fuels that are based on petroleum [1]. It is vital to search for alternative fuels that may be created from resources that are locally available inside the country such as alcohol, biodiesel, vegetable oil and so on because petroleum-based fuels are derived from restricted reserves. As a result, it is necessary to explore for alternative fuels. Over the past few years, a significant amount of investigation has put into the quest for viable alternatives to petroleum-based fuels. In this perspective, the utilization of renewable fuels such as ethanol, biogas and biodiesel as components of diesel fuel is significant. Currently, the fuels that we use are hydrocarbons like gasoline, diesel and coal. While we can continue to find these fuels for the next seventy-five years, in order to protect ourselves from impending danger, we need to look for other fuels to use in order to satisfy our basic energy requirements. It is possible to continue using

fuels such as biodiesel over the next 800 years. It would appear that biodiesel is an effective replacement fuel that can extend the use of diesel fuel.

Biodiesel is a fuel that is made from vegetable oils and as the name suggests, it is quite similar to diesel fuel [2]. The main difference is that biodiesel is made from oil crops that are more regularly farmed. Canola, sunflowers, soybeans and safflower are all great oil crops that may be cultivated in this location. Safflower is also farmed here. They are all capable of produce several gallons of gasoline per acre, which may be utilized in a diesel engine without requiring any modifications. Canola and sunflower, for instance, each have the potential to yield between seventy-five and one hundred gallons of vegetable oil per acre, the equivalent of roughly one hundred gallons of biodiesel [3]. Alternative fuels that are produced domestically from renewable sources and burn cleanly are collectively referred to as bio diesel. Although bio diesel does not include any petroleum, it can be mixed with diesel made from petroleum in any proportion to form a bio diesel blend. The industry name for diesel made from petroleum that is referred to as petrol diesel has a viscosity that is comparable to that of bio diesel. It is possible to utilize it as an addition in the formulation of diesel in order to boost the lubricity of pure ultra-low sulphur diesel

(ULSD) fuel, which is an advantage due to the fact that it contains almost no sulphur [4]. As a result, it needs very little, if any, modification in order to be used in engines that utilise compression ignition, such as diesel engines. In addition to being easy to work with, biodiesel is also harmless, biodegradable and mainly composed of sulphur and aromatics. Bio-diesel is the only alternative fuel that has fully satisfied the health effect testing criteria that was imposed by an amendment to the clean air act in 1990.

The sale and distribution of bio-diesel that satisfies the requirements of ASTM D6751 and is registered with the environmental protection agency in accordance with the law is permitted. Unrefined vegetable oil does not fulfill the requirements of biodiesel fuel. Bio-diesel is defined as amino-alkyl esters of long-chain fatty acids and it is produced by processing vegetable oil and animal fats in a manner that complies with the ASTM D6751 specification for use in diesel engines. The term "bio-diesel" refers to the blending of pure fuel with diesel fuel. Unrefined vegetable oils are used in the production of bio diesel in this experiment [5]. After the fish oil was extracted, its viscosity, flashpoint, fire point, specific gravity and other physical and chemical parameters were analyzed. Functional groups such as carbonyl, unsaturation; ester, glycerin, methylene and terminal methyl are present in fish oil in its natural state, which is very acidic. Fish oil also contains its terminal methyl group. The crude oil was bleached and a two-step transesterification method, known as acidic-alkaline. Transesterification, was created for the purpose of manufacturing methyl esters of fish oil.

The fact that oils often have a significant quantity of free fatty acids presents a challenge for the alkaline esterification process. These free fatty acids immediately react with an alkaline catalyst to form soap, which prevents the ester and glycerin from separating into their respective components. The initial procedure, known as acid catalyst esterification, brings the percentage of free fatty acids in the oil down to less than 2%. The result of the first stage is then subjected to an alkaline catalyzed trans-esterification in the second step, which transforms the product to its monoesters and glycerol. Biodiesel's viscosity is getting closer to that of diesel and its calorific value is 14% lower than diesel's. The characteristics of this bio-diesel fuel are quite similar to those of diesel fuels. Performance tests were run on a CI engine using varying proportions of fish oil and diesel blend and comparisons were made between the various fuels' respective proportions [6].

2. Preparation of FO, biodiesel and its procedure

The waste from preparing fish that was used in this study came from a fish market in Chennai. Biodiesel was made from fish waste, which was made up of the fish's less important parts like heads, tails, fins and organs. The tests were done with sodium hydroxide from Fischer Scientific Ltd., methanol from Hayman Specialty Products and potassium hydroxide from Merck India Ltd. The fish fat was taken out by heating the fish waste in a jar with three necks and a round bottom. Water was

used as a solvent. It is heated for about an hour in a heating plate at about 80°C. Then it was poured out for 30 minutes to get rid of the layer of fat. The fat layer had to be decanted again to finish the process of separating [7]. The extracted fat (10 ml) and the right amount of sodium hydroxide (25 ml) were mixed and stirred in an electronic shaker to start the saponification process. The solution is then spun in an Eppendorf 5430 centrifuge at 3000 rpm for 15 minutes to remove the saponified fat. 0.9775 g of potassium hydroxide was mixed with 17.4 g of methanol in a beaker and stirred constantly with a magnetic stirrer made of REMI 1MLH until the potassium hydroxide fully dissolved and formed potassium methoxide, a strong caustic. After the potassium methoxide was made, it was blended with 87.5 ml of the fish fat for 1 hour while being shaken. The mixture was then put into a funnel used to separate things [8]. After letting the contents settle, the top layer, which was bio-diesel and the bottom layer, which was glycerol, was taken apart.

After the glycerol was separated, the methyl ester was washed twice with water in a ratio of 1:1 for an hour to get rid of any extra methanol. The fuels were produced by combining diesel and fish oil in different proportions, such as 100:0 (pure diesel), 20:80 (20% of fish oil and 80% of diesel), 40:60 (40% of fish oil and 60% of diesel), 6:4 (60% of fish oil and 40% of diesel), 80:20 (80% of fish oil and 20% of diesel) and 100% (raw fish oil). These proportions were then tested for their flash point, fire point, viscosity, density. The characteristics of the different fuel blends overall performance were then evaluated one by one. In this scenario, a small amount of fuel is removed from the container at a time and added to the storage tank. Initial precautions are taken, which include checking the fuel level and making sure the pipes are correctly connected [9]. The information on the engine's name plate is then used to calculate the rated power, load and speed of the engine. Now that the engine has been started, a stopwatch is used to record the duration of time it takes for 10 cc of fuel to be consumed. Investigation into alternative fuels, a four-stroke diesel engine was used. The engine was set to a high idle speed of 1500 rpm and it was loaded to that speed for all of the tests. These tests were conducted with the intention of determining how well pure biodiesel and mixtures of biodiesel and diesel performed. It would appear that biodiesel makes an excellent replacement for diesel fuel. It is compatible with diesel fuel in any proportion and appears to maintain its mixed state even while being stored [10].

Residents are interested in a variety of ratios of diesel to fish oil, including 0:10, 4:6, 8:2, 6:4, 8:2, 8:2 (80% fish oil and 20% diesel) and 6:4 (60% fish oil and 40% diesel) (raw fish oil). Fish oil methyl ester is the type of biodiesel that is utilized. However, the performance was significantly diminished, despite the fact that the emissions were significantly higher. It is possible to power a diesel engine with diesel and fish oil without making any necessary adjustments to the engine itself. Fish oil is completely dissolved when diesel fuel is used. In the short term, the diesel engine can be used to repair components of other engines that have been damaged. It is recommended that the viscosity and

heating valve of the biofuel be lowered in order to circumvent these problems [11]. There are two methods for blending: volume-based blending and mass-based blending. Volume-based blending is the more common method. Combining the fuel is an effective strategy for reducing the heat valve and the viscosity of the fuel [12]. Five different compounds were produced as a result of diesel and fish oil being blended together. The properties of biodiesel as shown in Table. 1. B20 - 20% of fish oil + 80% of diesel fuel, B40 - 40% fish oil + 60% of diesel fuel, B60 - 60% of fish oil + 40% of diesel fuel, B80 - 80% of fish oil + 20% of diesel fuel, B100 -100% of fish oil + 0% of diesel fuel.

Table 1: Properties of FO and its blends

Property	Diesel	Fish oil	B20	B40	B60	B80
Density, kg/m ³	827	844	830.4	833.8	837.2	840.6
Viscosity @ 40°C	24.6	28.7	25.4	26.2	27.1	27.9
Calorific value, kJ/kg	45480	35178	43420	41359	39299	37238
Flash point, °C	52	84	58	65	71	78
Fire point, °C	257	185	243	228	214	199
Kinematic viscosity	3.52	56.86	30.26	4.07	5.46	7.02
Cetane No.	52	48	-	-	-	-

3. Experimental procedure

A compression ratio of 17.5:1, an inlet valve opening timing of 13obTDC and an injection pressure of 200 bars were used to perform performance and emission analysis for a variety of fish oil/diesel blends at a variety of loads ranging from zero to one hundred % load [13]. The schematic diagram of the experimental diagram is shown in Fig.1. The compression ratio was 17.5:1 and the inlet valve opening timing was 13obTDC. For the purpose of loading the engine, an eddy current dynamometer was utilized [14]. It is kept track of how long it takes for each load to consume 10 cc of gasoline. This application makes use of a single-cylinder Kirloskar engine that employs direct injection and has a compression ratio, inlet valve timing and injection pressure that are all typical, 1500 rpm is the continuous speed.

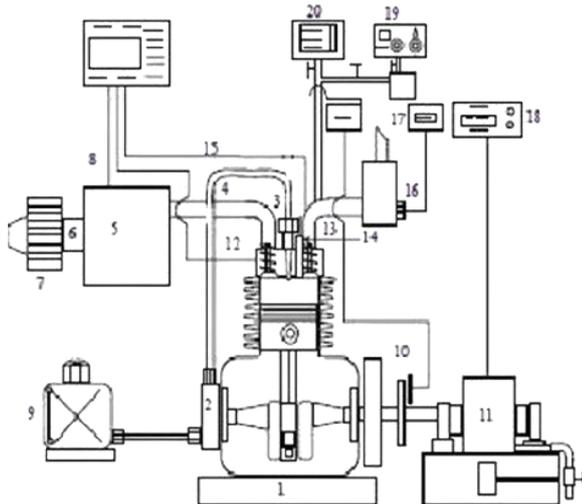


Fig. 1: Schematic diagram of experimental set-up

The components of exhaust gasses change depending on the load. To gather baseline data, the engine is initially run-on regular diesel oil. Then, several amounts of fish oil (FO), including 20%, 40%, 60%, 80% and 100%, are used to conduct the experiment. The reading for various blends is taken using the same process [15]. The components in fig. 1 are marked as 1. Engine and bed, 2. Fuel injection pump, 3. Fuel injection nozzle, 4. Intake manifold, 5. Intake air surge tank, 6. Air flow meter, 7. Air cleaner, 8. Intake air temp sensor, 9. Fuel tank, 10. Crank angle detector, 11. Electric dynamometer, 12. Coolant temp sensor, 13. Exhaust manifold, 14. Compression pressure, 15. Exhaust gas transducer temp sensor, 16. Air-fuel ratio sensor, 17. A/F meter, 18. Dynamometer control panel, 19. Gas analyzer, 20. Smoke meter. Table 2 represents engine specifications.

Table 2: Kirloskar TV 1 engine specifications

Specification	Value
No of strokes	4
No. of a cylinder	Single cylinder
Stroke	11 cm
Swept volume	0.661 liter
SFC	250 g/kW-hr
Speed	1500 rpm
Compression ratio	17.5:1
Max. power	5.2kW
Injection timing	23° bTDC
Cylinder bore	87.5 mm
Injection nozzle	3-hole Nozzle

4. Results and discussion

The thermal efficiency of the brakes demonstrates the performance of the fuel. The thermal efficiency of a vehicle's brakes is equal to its fuel economy per mile in reverse. As the load increases, the thermal efficiency of the brakes improves. Thermal efficiency refers to an engine's capacity to convert fuel energy into mechanical energy. The thermal efficiency of the brakes varies linearly with engine load for all fuels. As shown in Fig. 2, the thermal efficiency of the brakes at rated power is 32.0021% for diesel, 29.3727% for B20, 27.0952% for B40, 23.9685% for B60, 21.4627% for B80 and 18.2459% for B100. Fish oil and its blends have a worse braking thermal efficiency than diesel under all loading circumstances [16]. Diesel has a little greater brake thermal efficiency than blends. When using diesel fuel, it has been found that an engine's efficiency is 38% less than when using raw fish oil. This might be as a result of the fuel's higher viscosity, lower energy content and lower calorific value when compared to diesel. For fish oil and its blends, the main reasons for a reduction in braking thermal efficiency are poor atomization, incomplete combustion and poorer heat release. Additionally, a lower Cetane number and higher viscosity are contributing factors [17]. Additionally, larger aromatic bonds in fish oil take more energy to break, which lowers the thermal efficiency of the brakes.

The relationship between brake-specific fuel consumption (SFC) and engine load is shown in Fig. 3. diesel, B20, B40, B60 and B100 have SFC values of 0.266217 kg/kWh, 0.267546 kg/kWh, 0.293713 kg/kWh,

0.28747 kg/kWh, 0.301214 kg/kWh and 0.323367 kg/kWh respectively, at a load of 25%. According to the research, the fuel consumption of the tested fuels is highest when the engine is under low load, decreases as the load increases and becomes less significant when the engine is operating under higher loads [18]. The levels of SFC and BTE in diesel, fish oil and blends of those two fuels are inversely proportional to engine load. All of the fuels that were tested showed a decrease in their individual fuel consumption when the load was increased. At all weights, fish oil and its mixtures exhibit greater SFC values than diesel [19]. This can be explained by the fact that fish oil and its blends have lower combustion efficiency due to improper preparation of the air fuel mixture, which may be caused by the increased viscosity of fish oil.

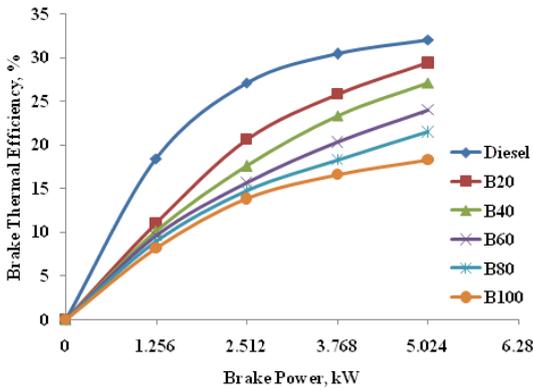


Fig. 2: Variation of brake thermal efficiency with respect to brake power for various blends of fish oil

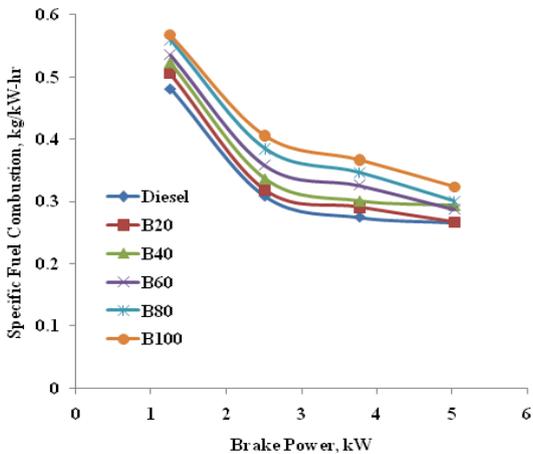


Fig. 3: Variation of SFC and brake power for several different fish oil blends

The SFC is decreased as the load on the engine rises, is higher for biodiesel made from fish oil and is lower for the blend (B20) when compared to diesel fuel. SFC increased in tandem with the load on the engine. When compared to diesel fuel, the SFC for B20 blends is 7.92% higher. One of the most important considerations to make is the vehicle's average fuel economy. When it comes to diesel fuel, the consumption of raw fish oil results in higher SFC [20]. The consumption of diesel fuel is 23% higher than the consumption of raw fish oil. Diesel has a lower SFC compared to blends. This could be because diesel has a higher viscosity than this does, which could explain why this is happening. Insufficient atomization is the root cause of delayed ignition.

Fig. 4 shows how the cylinder pressure varies with crank angle for diesel fuel (D100), B20, B40, B80, B60 and B100 when the engine is operating at full load. Due to its low viscosity and high instability, diesel fuel has a higher cylinder peak pressure (CPP) than biodiesel and its blends. As a result, it is crucial for atomization rate and air/fuel fraternization [21]. When compared to diesel fuel, the in-cylinder pressure drops from engines running on B20, B40, B60, B80 and B100 are determined to be 9.72%, 14.89%, 20.15%, 24.49% and 30.12% respectively. Peak pressure is decreased as a result of the charge's decreased oxygen concentration. Fig 5 shows how the rate of heat release changes with the crank angle when operating at full load and with three different injection timings. An initial negative heat release occurs due to fuel vaporization during the ignition delay, but these changes to a positive value once combustion has begun. 67.987 J/°CA and 47.587 J/°CA for B20 and B100 and 62.817 J/°CA and 57.563 J/°CA and 62.817 J/°CA for B100 are the respective heat emission rates. This is because biodiesel has a higher density and viscosity than conventional diesel, resulting in poor fuel atomization and mixing, which in turn causes a delayed ignition and reduced heat release [22, 23].

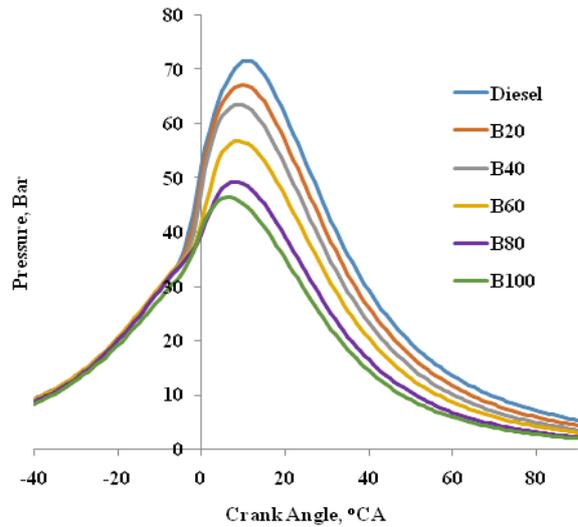


Fig. 4: Variation of crank angle with respect to pressure for various blends of fish oil

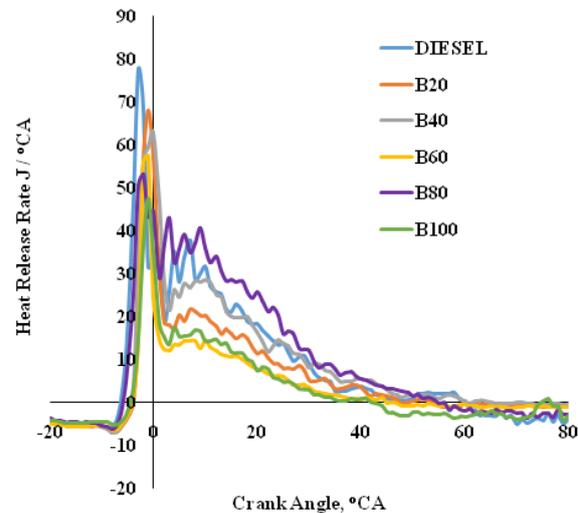


Fig. 5: Variation of crank angle with respect to heat release rate for various blends of fish oil

An AVL gas analyzer was utilized in order to get accurate readings of the exhaust gas emissions. Ozone is produced in significant part by emissions from large diesel engines. These emissions come from sources. As the load increased, so did the amount of CO that was emitted. The absence of sufficient oxygen in diesel engine's combustion chambers is the primary factor that contributes to the production of carbon monoxide during the combustion process [24, 25]. Under each and every loading condition, fish oil and the blends that contained it caused an increase in CO emissions. The consumption of diesel fuel is 23 % higher than the consumption of raw fish oil. Fig. 6 demonstrates that the CO emission for diesel changes from 0.157% at no load to 0.136% at full load, whereas the CO emission for fish oil 100 changes from 0.132% at no load to 0.104% at full load. One of the main elements directly affecting combustion efficiency is homogeneous charge mixing inside the engine cylinder. Diesel emits less carbon monoxide than fish oil and its blends. Unburned fuel molecules which cause hydrocarbon emissions, which are brought on by insufficient temperature close to the engine cylinder walls. Unburned hydrocarbon emissions are mostly caused by engine speed variations, messy fuel injection, injector needle bounce, etc.

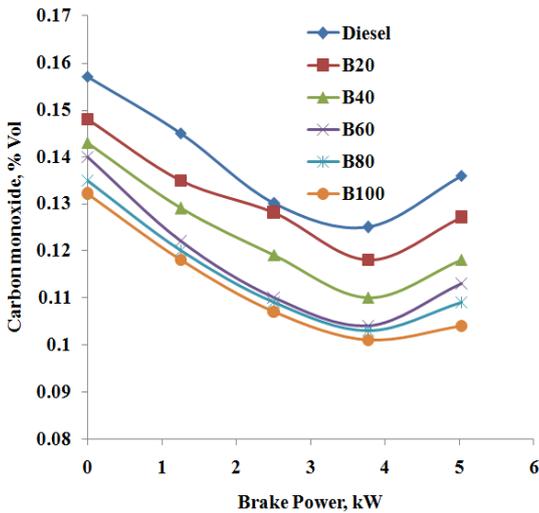


Fig. 6: Fluctuating levels of CO in relation to the braking power of various fish oil blends

Fig. 7 illustrates the quantity of UHC emission at full load for various fuels, with diesel emitting 52 PPM, B20 emitting 53 PPM, B40 emitting 56 PPM, B60 emitting 75 PPM, B80 emitting 84 PPM and B100 emitting 86 PPM. At all engine loads, fish oil and its blends have higher UHC emissions than diesel. Fish oil that isn't completely burned creates additional combustion [26, 27]. When the braking power increases, the hydro carbon increases. Improper mixture formation causes more HC emission. The heating capacity of an engine that is only burning diesel is 3% greater than the heating capacity of an engine that is burning a mixture of diesel and fish oil. After approximately 75% of the load, the HC emissions for each blend increased to a higher level than before. It's possible that the higher viscosity, density and volatility of the fish oil diesel mixes prevented them from being-atomized. Fig. 8 explains that the NO formation increases with load for all of the

tested fuels, with fish oil exhibiting the highest NO formation across the board. The NO emission levels for diesel range from 60 PPM when the engine is not under load to 615 PPM when it is fully loaded. Meanwhile, the NO emission levels for raw fish oil range from 115 PPM when the engine is not under load to 884 PPM when it is fully loaded. In diesel engines, the temperature inside the cylinder is an important factor that has a direct influence on the amount of NO that is produced. The temperature inside the cylinder rises along with the increase in NO emission, because fish oil has a lower Cetane number, a greater volume of fuel particles burns quickly, increasing peak pressure [28]. The amounts of available oxygen, reaction time and in-cylinder temperature all have a significant impact on NOx generation. Fig. 8 represents the experimental output results of nitrogen oxides. Hence, the temperature inside the cylinder rises, leading to more NO being released.

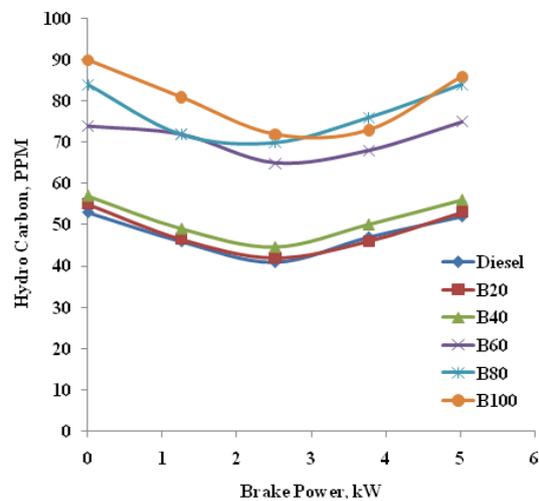


Fig. 7: Variation of HC with respect to brake power for various blends of fish oil

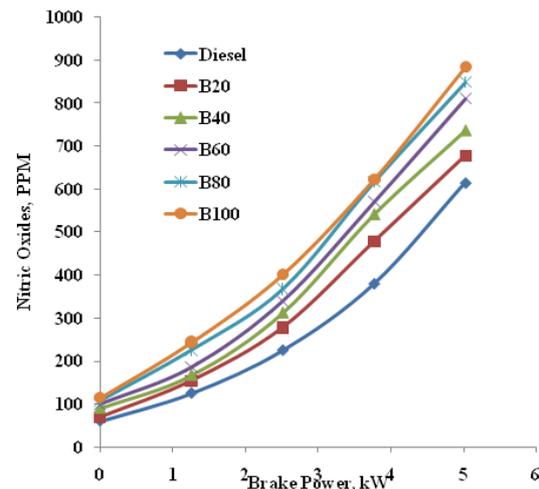


Fig. 8: Variation of Oxides of Nitrogen with respect to brake power for various blends of fish oil

Higher cylinder temperatures, resulting from increased combustion and the burning off of fuel hydrocarbons, are shown to increase NOx levels under load. In terms of part per million, B80's NOx goes from 108 at light load to 849 when the engine is working harder. Specifically, for B20, NOx increases from 69 parts per million (PPM) at low engine load to 678 PPM

at higher engine load and for B40, NO_x increases from 90 PPM at low engine load to 736 PPM at higher engine load. There is less nitrogen oxide (NO_x) pollution from using fish oil biodiesel than from using diesel fuel and this pollution decreases with increasing concentrations of the two. Since biodiesel contains fewer nitrogen oxides, it ignites more easily than diesel. NO_x emissions rise with increasing load but fall with increasing biodiesel content. When compared to diesel, biodiesel has a better igniting process, primarily due to lower NO_x [29, 30]. When the load is increased, the NO_x increases and when the biodiesel content of the mixtures is increased, the NO_x reduces. Fig. 9 shows how the smoke output varies with engine load. Diesel smoke emissions range from 18.7 HSU at no load to 65.2 HSU at maximum load, while fish oil smoke emissions range from 9.72 HSU at no load to 46.98 HSU at maximum load. In comparison to diesel fuel, fish oil and its mixtures produce more smoke. The primary factor that contributes to an increase in the amount of smoke generated is the presence of a greater number of aromatic components in fish oil and its blends. The higher viscosity of fish oil and its mixtures, as well as the lower volatility of these substances, are two additional factors that contribute to increased smoke emissions [31, 32]. These factors have a significant influence on the manner in which the air-fuel mixture is prepared inside the cylinder of the engine, which results in combustion that is less efficient. As a direct consequence of this, the efficiency with which fish oil and its derivatives are burned is diminished, which leads to an increase in the quantity of smoke generated.

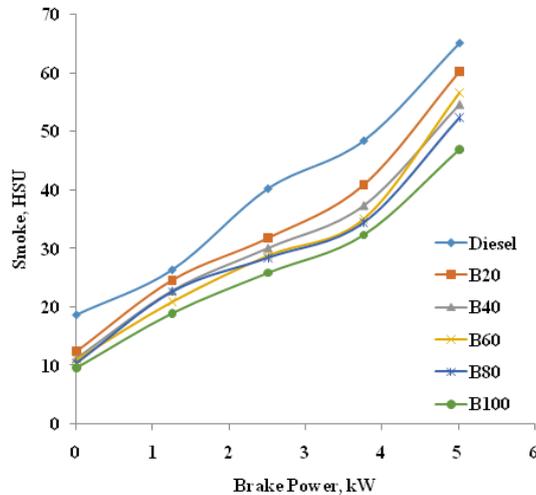


Fig. 9: Variation Smoke in relation to brake power for various fish oil blends

The temperature has a much greater influence on the cause of this. It has been demonstrated that raw fish oil mixtures emit 40% less smoke than diesel engines. As the engine load increases, factors such as the overall richness of the air fuel ratio, the lengthening of the diffusion combustion phase and the decreased oxygen concentration all contribute to increased smoke opacity. Smoke production increases due to inefficient fuel atomization as well as insufficient combustion. It displays the smoke number, emission levels for fish oil diesel fuel and B20, B40, B60 and B100 at full load for a variety of engine loads. When the engine is operating at

its maximum capacity, a greater quantity of gasoline is burned in order to produce the desired level of power. This results in an increase in the amount of smoke that is produced. When using fish oil diesel fuel in any of its forms (B20, B40, B60, B80 and B100), the level of smoke emitted by the engine increased as the load on the engine increased. The mixture becomes richer when more fuel is added to the cylinder; however, the fuel is burned more incompletely, which results in increased smoke production. Adding more fuel also increases the temperature of the mixture. The results of the experiment indicate that the levels of energy density contained in biodiesel and biodiesel blends are noticeably higher than those contained in diesel. Incorrect fuel-air mixing is typically brought on by biodiesel's high viscosity, which is a major contributor, as well as its low volatility. Both of these characteristics are major contributors. The high molecular weight of biodiesel is one factor that contributes to the increased smoke it produces [33-35]. The percentage of biodiesel that contributes to smoke emissions when the engine is operating at full load, 7% for B20, 16% for B40, 13% for B60, 19% for B80 and 27% for B100, when compared to diesel fuel.

5. Conclusion

The research summary was derived from an ongoing experimental study of a single-cylinder diesel engine powered by diesel-fish oil mixtures. The engine can be run by gradually adding more bio-fuel to the diesel fish oil and the different blends provide a different driving experience for each blend. The heating valve and density increases of the fish oil-diesel blend are properties that are compared to bio-fuel and found to be superior. The four-stroke diesel engine operates without requiring any adjustments. Out of the five different blends, the one that contains 20% fish oil and diesel performs the best in terms of performance and emissions. The other blends contain 40%, 60%, 80% and 100% fish oil and diesel respectively. The proportions of B20 (20:80) diesel and fish oil blends have a better brake thermal efficiency than other blends when the loading conditions are higher. When compared to other blends, it contributes to an improvement of between 1% and 2%. It was found that thermal efficiency could be improved with lower concentrations of biodiesel blends containing fish oil. The thermal efficiency of diesel engine brakes is improved when they are operated with a B20 biodiesel blend. The proportions of B20 (20:80) diesel and fish oil show a higher brake thermal efficiency when compared to other blends. This is because B20 contains a higher proportion of fish oil. In terms of performance, it outperforms a variety of other blends. The density of smoke in the exhaust gas decreases proportionally with increasing concentrations of biodiesel blend. As a consequence of this, the proportions 20:80 are suggested for the best performance from diesel.

REFERENCES:

- [1] A. Gashaw and A. Lakachew. 2014. Production of biodiesel from non-edible oil and its properties, *Int. J. Sci., Env. & Tech.*, 3(4), 1544-1562.

- [2] A. Shirneshan. 2013. HC, CO, CO₂ and NO_x emission evaluation of a diesel engine fueled with waste frying oil methyl ester, *Proc. - Social & Behavioral Sci.*, 75, 292-297. <https://doi.org/10.1016/j.sbspro.2013.04.033>.
- [3] S. No. 2011. Inedible vegetable oils and their derivatives for alternative diesel fuels in CI engines: A review, *Renewable & Sustainable Energy Reviews*, 15(1), 131-149. <https://doi.org/10.1016/j.rser.2010.08.012>.
- [4] R.J.G.R. Nimal and S. Jacob. 2023. Ensembles of decision rules to predict brake thermal efficiency of bio diesel with nanoparticles, *Knowledge Trans. Applied Machine Learning*, 1(3), 18-29. <https://doi.org/10.59567/ktAML.V1.03.02>.
- [5] S. Kirankumar, R. Nagendrababu and K. Apparao. 2015. Engine performance and emissions with ethanol and diesel-biodiesel blends, *Int. Research J. Engg. & Tech.*, 2(5), 1297-1303. <https://doi.org/10.59567/ktAML.V1.03.02>.
- [6] R. Sabarish and M. Premjeyakumar. 2019. Experimental investigation of single cylinder diesel engine by diesel - citrullus vulgaris with n-butanol and its blends, *J. Mechanics Continua & Math. Sci.*, 2, 653-672. <https://doi.org/10.26782/jmcs.spl.2019.08.00080>.
- [7] K. Kalaimurugan, S. Karthikeyan, M. Periyasamy, G. Mahendran and T. Dharmaprabakaran. 2019. Experimental studies on the influence of copper oxide nanoparticle on biodiesel-diesel fuel blend in CI engine, *Energy Sources, Part A: Recovery, Utilization & Environmental Effects*, 45(3), 8997-9012. <https://doi.org/10.1080/15567036.2019.1679290>.
- [8] K. Muralidharan, D. Vasudevan and K.N. Sheeba. 2011. Performance, emission and combustion characteristics of biodiesel fuelled variable compression ratio engine, *Energy*, 36(8), 5385-5393. <https://doi.org/10.1016/j.energy.2011.06.050>.
- [9] M.A. Asokan, S.S. Prabu, S. Kamesh and W. Khan. 2018. Performance, combustion and emission characteristics of diesel engine fuelled with papaya and watermelon seed oil bio-diesel/diesel blends, *Energy*, 145, 238-245. <https://doi.org/10.1016/j.energy.2017.12.140>.
- [10] J.S. Basha and R.B. Anand. 2014. Performance, emission and combustion characteristics of a diesel engine using carbon nanotubes blended jatropha methyl ester emulsions, *Alexandria Engg. J.*, 53(2), 259-273. <https://doi.org/10.1016/j.aej.2014.04.001>.
- [11] M.S. Kocak, E. Ileri and Z. Utlu. 2007. Experimental study of emission parameters of biodiesel fuels obtained from canola, hazelnut and waste cooking oils, *Energy & Fuels*, 21(6), 3622-3626. <https://doi.org/10.1021/ef0600558>.
- [12] E. Ileri and G. Kocar. 2013. Effects of antioxidant additives on engine performance and exhaust emissions of a diesel engine fueled with canola oil methyl ester-diesel blend, *Energy Conversion & Mgmt.*, 76, 145-154. <https://doi.org/10.1016/j.enconman.2013.07.037>.
- [13] K. Ramalingam, D. Balasubramanian, P.J.T.J.S. Chellakumar, J. Padmanaban, P. Murugesan and T. Xuan. 2020. An assessment on production and engine characterization of a novel environment-friendly fuel, *Fuel*, 279. <https://doi.org/10.1016/j.fuel.2020.118558>.
- [14] M. Kunjan, J.J. Jayaraj, B. Joseph, M. Govindaraj, R.B.D. Raj and A. Poovannan. 2016. Biodiesel derived from mango seed oil as an alternative fuel for diesel, *Research J. Pharmaceutical, Bio. & Chem. Sci.*, 7(6), 2137-2143.
- [15] B. Dhinesh, Y.M.A. Raj, C. Kalaiselvan and R.K. Moorthy. 2018. A numerical and experimental assessment of a coated diesel engine powered by high performance nano biofuel, *Energy Conversion & Mgmt.*, 171, 815-824. <https://doi.org/10.1016/j.enconman.2018.06.039>.
- [16] P. Sathiamurthi, K.S.K. Vinith and A. Sivakumar. 2019. Performance and emission test in CI engine using magnetic fuel conditioning with nano additives, *Int. J. Recent Tech. & Engg.*, 8(3), 7823-7826. <https://doi.org/10.35940/ijrte.C6213.098319>.
- [17] M. Zhu, Y. Ma and D. Zhang. 2012. Effect of a homogeneous combustion catalyst on the combustion characteristics and fuel efficiency in a diesel engine, *Applied Energy*, 91(1), 166-172. <https://doi.org/10.1016/j.apenergy.2011.09.007>.
- [18] J.K. Efavi, D. Kanbogtah, V. Apalangya, E. Nyankson, E.K. Tiburu, D.D. Arhin, B.O. Agyeman and A. Yaya. 2018. The effect of NaOH catalyst concentration and extraction time on the yield and properties of Citrullus vulgaris seed oil as a potential biodiesel feed stock, *South African J. Chem. Engg.*, 25, 98-102. <https://doi.org/10.1016/j.sajce.2018.03.002>.
- [19] J.M. Paul and D. Gowdham. 2016. Emission characteristics of cerium oxide nanoparticle blended emulsified biodiesel, *Int. J. Advances Sci. Engg. & Tech.*, 4(2), 155-158.
- [20] A.K. Agarwal, A. Dhar, J.G. Gupta, W.I. Kim, K. Choi, C.S. Lee and S. Park. 2015. Effect of fuel injection pressure and injection timing of karanja biodiesel blends on fuel spray, engine performance, emissions and combustion characteristics, *Energy Conversion & Mgmt.*, 91, 302-314. <https://doi.org/10.1016/j.enconman.2014.12.004>.
- [21] M. Pugazhivadivu and K. Jeyachandran. 2005. Investigations on the performance and exhaust emissions of a diesel engine using preheated waste frying oil as fuel, *Renewable Energy*, 30(14), 2189-2202. <https://doi.org/10.1016/j.renene.2005.02.001>.
- [22] M. Muthukumar, A.P.S. Kumar, C. Sasikumar, S. Yuvaraj and T.S. Singh. 2021. Effect of nanoparticles on the droplet combustion of rice bran oil biodiesel, *Biomass Conversion & Biorefinery*, 11, 1375-1393. <https://doi.org/10.1007/s13399-020-01209-8>.
- [23] F. Lujaji, A. Bereczky, L. Janosi, C. Novak and M. Mbarawa. 2010. Cetane number and thermal properties of vegetable oil, biodiesel, 1-butanol and diesel blends, *J. Thermal Analysis & Calorimetry*, 102, 1175-1181. <https://doi.org/10.1007/s10973-010-0733-9>.
- [24] R. Sabarish, M. Premjeyakumar and R. Rajasekar. 2022. Experimental investigation on direct injection diesel engine fuelled by JFO with nano additives, *Mat. Today: Proc.*, 62(4), 1821-1829. <https://doi.org/10.1016/j.matpr.2021.12.456>.
- [25] R.S. Dsilva, K. Vinoothan, B.K. Gopalakrishna T. Bhat and K. Raju. 2016. Effect of titanium dioxide and calcium carbonate nano additives on the performance and emission characteristics of CI. engine, *J. Mech. Engg. & Automation*, 6(5A), 28-31.
- [26] A. Syed, S.A.P. Quadri, G.A.P. Rao and M. Wajid. 2017. Experimental investigations on DI diesel engine operated on dual fuel mode with hydrogen and Mahua oil methyl ester (MOME) as injected fuels and effects of injection opening pressure, *Applied Thermal Engg.*, 114, 118-129. <https://doi.org/10.1016/j.applthermaleng.2016.11.152>.

- [27] C. Sivakandhan, P.V. Elumalai, M. Murugan, A. Saravanan, P.S. Ranjit and B. Varaprasad. 2022. Effects of on MnO₂ nanoparticles behavior of a sardine oil methyl ester operated in thermal barrier coated engine, *J. Thermal Analysis & Calorimetry*, 147, 8919-8931. <https://doi.org/10.1007/s10973-021-11132-3>.
- [28] T. Ramesh, A.P. Sathiyagnanam, M.V.D. Poures and P. Murugan. 2022. Combined effect of compression ratio and fuel injection pressure on CI engine equipped with CRDi system using Prosopis juliflora methyl ester/diesel blends, *Int. J. Chem. Engg.*, 2022, 1-12. <https://doi.org/10.1155/2022/4617664>.
- [29] S.S. Prabu, M.A. Asokan, S. Prathiba, S. Ahmed and G. Puthean. 2018. Effect of additives on performance, combustion and emission behavior of preheated palm oil/diesel blends in DI diesel engine, *Renewable Energy*, 122, 196-205. <https://doi.org/10.1016/j.renene.2018.01.068>.
- [30] M. Christopher and R. Sabarish. 2014. Emission analysis of a single cylinder DI engine running on biodiesel blend as fuel, *Middle-East J. Scientific Research*, 20(6), 681-684. <https://10.5829/idosi.mejsr.2014.20.06.11377>.
- [31] U. Agbulut, M. Ayyıldız and S. Sarıdemir. 2020. Prediction of performance, combustion and emission characteristics for a dual fuel diesel engine at varying injection pressures, *Energy*, 197, 117257. <https://doi.org/10.1016/j.energy.2020.117257>.
- [32] S.N. Harikrishnan and R. Sabarish. 2014. Experimental analysis of direct injection diesel engine using rubber seed oil, *Middle-East J. Scientific Research*, 20(6), 709-714.
- [33] R. Sabarish and M. Premjeyakumar. 2020. Experimental Investigation of Single Cylinder DI Diesel Engine by diesel-JFO and its blends, *Proc. 3rd Int. Conf. on Frontiers in Automobile and Mech. Engg.*, Chennai, India. <https://doi.org/10.1063/5.0034018>.
- [34] J. Lee and S. Saka. 2010. Biodiesel production by heterogeneous catalysts and supercritical technologies, *Bioresource Tech.*, 101(19), 7191-7200. <https://doi.org/10.1016/j.biortech.2010.04.071>.
- [35] O.S. Tyagi, N. Atray, B. Kumar and A. Datta. 2010. Production, characterization and development of standards for biodiesel-A review, *J. Metrology Society of India*, 25, 197-218. <https://doi.org/10.1007/s12647-010-0018-6>.