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EVALUATE THE EFFECTS OF BIODIESEL FUEL SOURCES ON COMMON RAIL ENGINE PERFORMANCE AND EMISSIONS

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ABSTRACT
Biodiesel is considered an alternative fuel by reducing atmospheric and greenhouse gas pollutants. Biodiesel is usually produced from plants, algae, animals, or waste oil. This study evaluated the effects of different biodiesels, including fish diesel oil from fish (B20) and waste oil (BA20), compared to the standard diesel fuel (B0) on diesel engines at 1400 (rpm) corresponding to the torque of the maximum value. At the speed of 2200 (rpm), the fuel consumption is located within the region with the lowest value with different engine loads of 25% to 75%. The results showed that when the engine runs the B20 and BA20 fuel, the emissions decreased correspondingly to B0: with carbon monoxide (CO) corresponding to 15.39% and 19.50%; With non-burning hydrocarbon (HC), equivalent to 7.33% and 11.06% and the amount of Smoke emissions decreased by 21.56% and 15.47%; While nitrogen oxide (NOx) emissions increased, equivalent to 6.86% and 4.31% respectively.
Keywords: Diesel Engine, Engine Efficiency, Engine Emissions, Biodiesel, Common Rail Engine.
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INTRODUCTION

Recently, the energy demand has increased rapidly due to the significant growth of several developing economies. At the same time, the imposition of strict emissions regulations and the future depletion of petroleum fuel reserves have spurred the search for new technologies to develop alternative fuels and reduce emissions.[1,2] biodiesel is considered a clean fuel and does not require changes to the engine structure when used.[3,4] When using biodiesel fuel for the engine, the engine's performance and capacity are slightly reduced. Still, emissions are improved compared to diesel fuel.[5,6] Some researchers have also reported that biodiesel can produce engine power like diesel oil. Because of better ignition quality and higher internal oxygen content available to burn allows for increased burning efficiency.[7,8] The improved combustion process reduces the creation of smoke and the total amount of hydrocarbon emissions.[9,10] In contrast, a slight increase in nitrogen oxide is observed due to the higher burning temperature.[11,12] Most studies show that biological diesel oil can reduce the effectiveness of material particles and carbon monoxide; Hydrocarbon does not burn out But slightly increases nitrogen oxide compared to diesel fuel.[13,14] Various origins can affect their physical and chemical properties, such as viscosity, Cetane number, etc., affecting engine performance and emissions. For example, author Fujia *et al.,* in 2009, conducted experiments with biodiesel fuel sources, and the results were:[15] The results showed that using different types of biodiesels significantly reduced the amount of fine dust from 53% to 69%. However, other types of biodiesels also increase NO_x emissions by an average of 10 to 23%. The reduction in NO_x emissions is due to biodiesel fuel having a higher Cetane number. When the proportion of biodiesel from different sources increased, the amount of carbon hydrogen and particulate waste decreased compared to diesel fuel. This study tested a diesel engine's combustion process, performance, and emissions using a biodiesel fuel mixture. This fuel is derived from fish and waste oil at different engine loads (25%, 50% and 75% load). This is the job that needs to be done for this study. Because no research has evaluated the effect of biodiesel from fish oil with other fuels. In the combustion process study, the performance and emissions of biodiesel from fish oil waste oil were compared with diesel fuel through experimental

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research on the AVL-5402 diesel engine. To comprehensively comprehend the B20 and BA20 fuel blends, measurements were taken for cylinder engine energy, brake fuel consumption, and emissions.

EXPERIMENTAL

Fuel Used in Research

Test fuel includes conventional diesel fuel (B0); Biodiesel fuel originating from fish fat is mixed at a ratio of 20% (B20); Biodiesel fuel originating from waste fried oil is mixed at a ratio of 20% (BA20). Biodiesel fuels have a slightly higher viscosity than diesel fuel, so there is no need to use the fuel heating system. Biodiesel B20 and BA20 are fuel-rich fuels that can burn with small air residues while ensuring complete fire. On the other hand, Biodiesel's Cetane index is higher than vegetable oil but smaller than diesel, so the burning time is significant. The characteristics of the test fuels can be found in Table-1.

Table-1: Test Fuel

Parameter	B0	B20	BA20	ASTM
Thermal treatment (MJ/kg)	42.76	41.84	41.47	D240
Cetane value	49	51	52	D613
Density is at 15°C (kg/m^3)	838	845	855	D1298
History viscosity at 40°C (CST)	3.22	3.47	3.54	D445
Lightning point (^{0}C)	67	75	79	D93
Sulfur composition (ppm)	428	433	428	D5453
Water composition (ppm)	62	96	98	D6304

Experimental Engine

The engine (AVL-5402) was used as a reference point in the experimental study. Table-2 shows the basic technical parameters of the engine.

Table-2: Basic Parameters of AVL-5402 Engine

No	Parameter	Value	Unit
1	Work volume (V_h)	510.7	cm^3
2	Compression ratio (ε)	17.3	-
3	Maximum power (N_{emax})	9	Kw
4	The speed at N_{emax} (n_{Ne})	3200	rpm
5	Maximum moment (M_{emax})	29.3	Nm
6	Speed at M_{emax} (n_{Me})	1400	rpm
7	Brake specific fuel consumption ($BSFC_{min}$)	231.4	g/kW.h
8	The speed at $BSFC_{min}$ (n_{BSFC})	2200	rpm

Diagrams and Experiments

The diagram of a cylinder engine is a cluster of separate systems combined to form a testing system and research on internal combustion engines such as:

Dyno-AMK electrical test tape, AVL5402 cylinder research engine, AVL577 lubricating oil cooling system, AVL577 cooling water, Fuel Balance 733S fuel consumption device, THA100 scooter control device; Puma testing and monitoring system; ECU control system provides fuel for Inca engine; Pressure measurement device in indicating cylinder; The device determines the concentration of CEB-II emissions; The device determines the opacimeter smoke level 439; Smoke Meter, and some other auxiliary devices. The schematic of the test tap is depicted in Fig.-1.

Operating through the mutual magnetic field between the rotor and stator, the electric brake assembly on the single-cylinder engine test bench is a generator. The test can be conducted with torque and speed limits of 150Nm and 1800 rpm. Fuel Balance: The fuel balance device (AVL733S) measures the engine's fuel consumption. The fundamental parameters of this apparatus are extensively outlined in Table-3. The basic parameters of this device are described in detail in Table-3.

CEB-II Emissions Analyzer

The CEB-II exhaust analyzer (Combustion Emission Bench) is a system that includes all modules that perform the process of analysis of emissions components (analysts). The equipment ensures the exact working conditions of the system, such as: (HSU), diagnostic block, control block, etc. The analysts installed in the cabinet are used to measure the components in emissions such as CO, CO_2, Oxygen, NO_x, and HC, At the same time, the air residue is measured with an accuracy of 0.1%. Smoke meter device: Smoke Meter (AVL 415) will measure smoke in engine exhaust, measuring the maximum value of 3199 mg/m^3 with an accuracy of 0.1%.

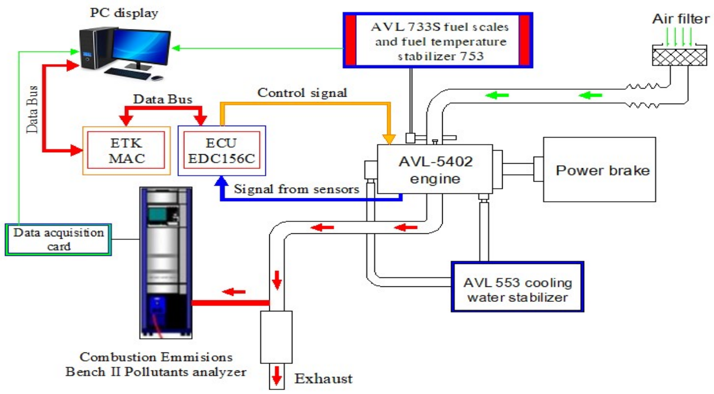

Fig.-1: Diagram of 1-Cylinder Engine Test Tape

Table-3: Specifications of Fuel Consumption Equipment

No	Parameter	Measuring range
1	Fuel temperature range	($-10^0C \div 70^0C$)
2	Conventional gauges	($0 \div 150$ kg/h)
3	Fuel pressure provided	($0.1 \div 0.8$ at)
4	The accuracy of the device	(± 0.12%)
5	Operating environment temperature	$0\ ^0C \div 60\ ^0C$

Test Mode

Establish the engine's external characteristic curve to ascertain the maximum torque value (M_{emax}). The experiment involved varying the load under a pressure of 600 bar, and the resulting shallow characteristic curve is depicted in Fig.-2. Utilize the M_{emax} value and multiply it by coefficients 0.75, 0.50, and 0.25 to determine the loads corresponding to 75%, 50%, and 25%. The early injection angle at 1400 rpm is 14 degrees, while at 2200 rpm, it is 18 degrees. Fuel was supplied for an unmodified cycle for all test fuels.

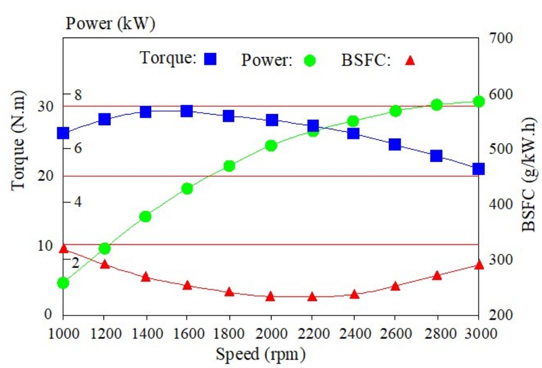

Fig.-2: The Actual External Characteristics of the Test Engine

For fuels B10, B20, and BA20, proceed to spray fuel under the injection pressure of B0 fuel, but make sure that the amount of fuel provided in the cycle does not change. From there, determine the corresponding spray time. The testing process for studying the damaged image of some different biodiesel sources in the engine is conducted as follows:

Step-1: Mix biological diesel fuel from fish fat and waste fried oil at a 20% rate. Specifically, biodiesel fuel from fish fat is B20, and waste fried oil is BA20.

Step-2: Keep the spray pressure constant at 600 bar. The early spray angle at 1400 (rpm) is 14 degrees, and at 2200 (rpm) is 18 degrees.

Step-3: Perform the test at load mode (25%, 50%, and 75%) at two speeds of 1400 rpm and 2200 rpm for three separate fuel types.

RESULTS AND DISCUSSION

Engine Efficiency

The capacity of the test fuel at the different load modes and speeds is shown in Fig.-3(a) and Fig.-3(b). Accordingly, engine power when using B20 and BA20 fuel is lower at all load values than fuel B0. The capacity of B20 fuel is higher than that of BA20 fuel. The change in output power is due to the fuel's thermal treatment. The most significant heat of B0 fuel is the largest capacity; of the minor BA20 fuel, the smallest capacity corresponds.

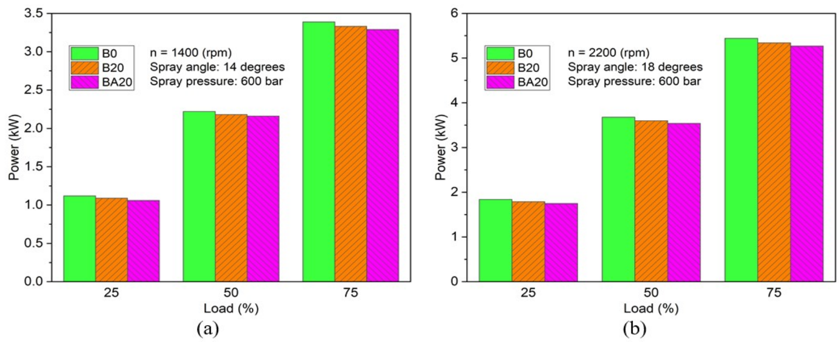

Fig.-3: Power Versus Load Graph of Biodiesel Fuel at (a) 1400 rpm speed and (b) 2200 rpm speed

Meanwhile, examine the Brake Specific Fuel Consumption (BSFC) difference between the lowest (B0) and the highest (BA20). Obviously, with the same amount of BSFC supplied to the same cycle, the corresponding BSFC increases when the power decreases. Fig.-4(a) and Fig.-4(b) show the engine's BSFC for fuels B0, B20, and BA20.

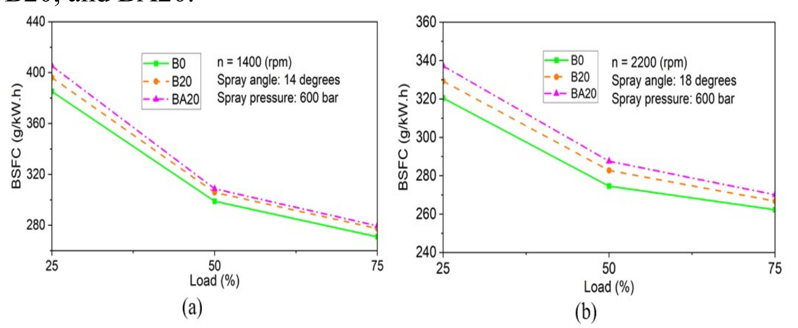

Fig.-4: Graph of Brake Specific Fuel Consumption According to Load at (a) Speed 1400 rpm and (b) Speed 2200 rpm

Fig.-4(a) and Fig.-4(b) show that, in small loads (25%), the difference in BSFC is relatively straightforward, while in medium ears and large loads, there are almost no significant distinctions in BSFC between fuels. The change in fuel consumption in both speed modes is the same.

Effect of Biodiesel Source on Combustion Characteristics

The maximum pressure with different loads and fuel sources is shown in Table-4. The maximum pressure of biodiesel fuel tends to move toward the top dead center.

Table-4: The Peak Pressure Value of the Test Fuel

Fuel		B0	B20	BA20
Speed	Load			
1400 (rpm)	25%	54.49	53.05	52.47
	50%	59.69	57.23	56.39
	75%	66.59	65.25	64.68
2200 (rpm)	25%	63.21	61.86	61.33
	50%	69.37	67.20	66.93
	75%	74.62	72.99	72.31

Biological diesel fuel has a higher viscosity, making it difficult for the misting process, resulting in the amount of a mixture of air and fuel prepared during the decrease in fire period; So the process of fire quickly takes place earlier. The peak pressure of biodiesel fuel is lower than diesel fuel, as evidenced by the heat release rate within the cylinder.

Evaluation of Emissions

Because the study of using different biological diesel fuels to compare with diesel fuel, HC, NOx, and smoke emissions are taken to evaluate in the experiment of the day exhaust.

CO Emissions

CO emissions at two modes 1400(rpm) and 2200(rpm), are shown in Fig.-5. CO emissions arise as a byproduct of combustion in the absence of oxygen. The engine needs more air at low speeds during the burning process.[16] When the engine uses biological diesel fuel, due to the oxygen biodiesel fuel, it reduces bold mixed areas and reduces CO. Integrating biodiesel fuel is essential due to its elevated oxygen content compared to traditional diesel fuel. This elevated oxygen content in biodiesel molecules effectively reduces dark mixed areas, promoting a cleaner combustion process within the cylinder.[17] As a result, using biodiesel leads to a decrease in exhaust gas volume. The average CO emissions values for both speed modes with B20 and BA20 are 15.39% and 19.50%, respectively, compared to using B0, as shown in Fig.-5(a) and Fig.-5(b). The average CO emissions values for both speed modes with B20 and BA20 are 15.39% and 19.50%, respectively, in contrast to using B0, as illustrated in Fig.-5(a) and Fig.-5(b). Furthermore, the decline in emissions for B20 is more prominent than the corresponding values for BA20 at speeds of 1400 rpm and 2200 rpm, registering 4.51% and 5.36%, respectively.

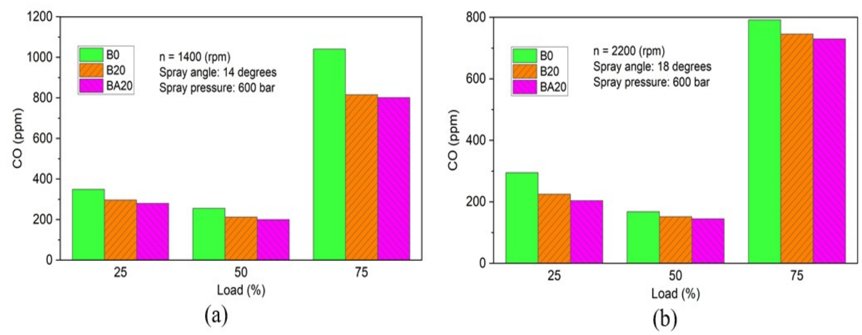

Fig.-5: CO Emission Graph According to Load at (a) Speed 1400 rpm and (b) Speed 2200 rpm

HC Emissions

The engine testing evaluates HC emissions in two modes, 1400 (rpm) and 2200 (rpm) in Fig.-6(a) and Fig.-6(b).The increased oxygen content and reduced viscosity in biodiesel contribute to a thorough and clean combustion process, reducing HC emissions.[18] When using biodiesel fuel, the ignition time is slower and creates better combustion than diesel fuel, so the low HC emissions are due to the higher cetane number value compared to diesel fuel.[19]

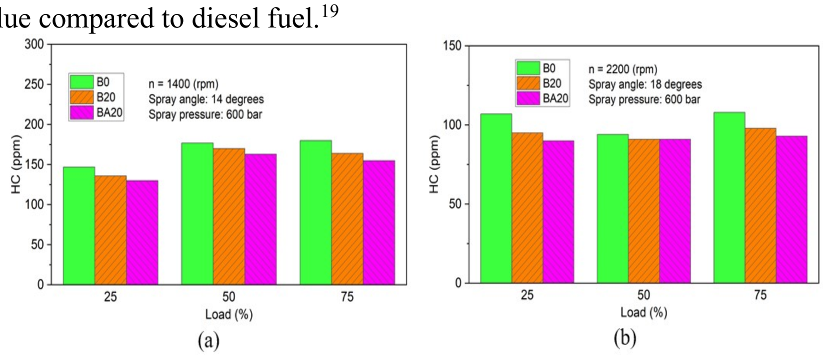

Fig.-6: HC Emission Graph According to Load at (a) Speed 1400 rpm and (b) Speed 2200 rpm

At each speed mode, HC emissions do not significantly differ between the load modes. HC emissions from fuel B0 consistently surpass those from B20 and BA20 in every load mode. The average HC emissions when using B20 and BA20, respectively, are 7.33% and 11.06%, as opposed to using B0. Meanwhile, emissions in the 2200 (rpm) mode are always lower than in the 1400 (rpm) mode for each load regime; the value is clearly stated in Fig.-6(a) and Fig.-6(b). This shows that in high-speed mode, increased vortex speed helps the mixture blend better and, therefore, will burn more. Meanwhile, the HC emissions of the B20 are more significant than the corresponding BA20 at the speeds n = 1400 (rpm) and n = 2200 (rpm), which are 4.67% and 3.46%. The higher Cetane value of the BA20 fuel helps the mixture easily catch fire and reduces the affluent fuel areas, so HC decreases.

NO_x Emissions

The engine testing assesses NO_x emissions in two modes, 1400 (rpm) and 2200 (rpm) in Fig.-7(a) and Fig.-7(b).

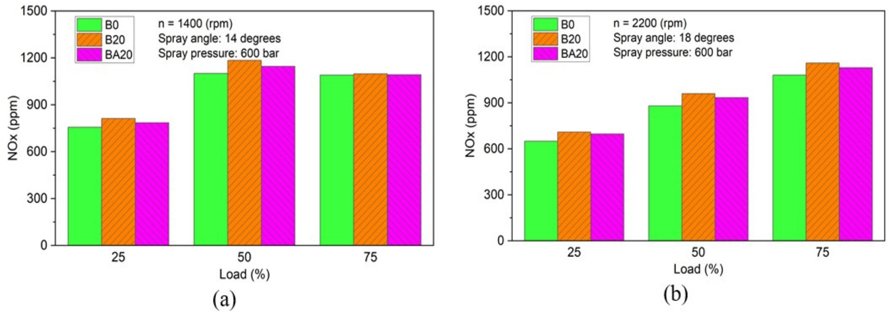

Fig.-7: NO_x Emission Graph According to Load at (a) Speed 1400 rpm and (b) Speed 2200 rpm

NO_x is a product of nitrogen oxidation in the air at high temperatures. Because nitrogen has many valences, nitrogen oxidates exist in many forms, collectively called NO_x.[19] NO_x emissions of B20 and BA20 are always higher than B0 at all load values. The average NOx emissions with B20 and BA20 are 6.86% and 4.31%, respectively, compared to B0, as depicted in Fig.-7(a) and Fig.-7(b). This variation is due to the increased oxygen residues in biodiesel fuel, promoting NO_x formation; furthermore, the higher cetane value of the biodiesel blend accelerates combustion compared to diesel fuel, leading to higher combustion temperatures.[15] Meanwhile, the NO_x emissions of the B20 are more significant than the corresponding value of the BA20 at the speed n = 1400 (rpm) and n = 2200 (rpm) are: 2.39% and 2.34%, Demonstrating the fire temperature of the engine when using the B20 is higher than the BA20. This is explained by the higher BA20 fuel that helps reduce the time of the fire and the amount of mixture during the fast fire period. The results of the temperature in the cylinder decrease, so NO_x decreases.

Smoke Emissions

Smoke emissions in two modes, 1400 (rpm) and 2200 (rpm), are shown in Fig.-8. Smoke is a significant pollutant in diesel engine emissions. The diffusion of diesel engines tends to facilitate smoke formation. In contrast, engines utilizing biodiesel fuel experience significantly reduced smoke emissions, primarily attributed to oxygen elements in the fuel component, enhancing the thoroughness of the oxidation process.

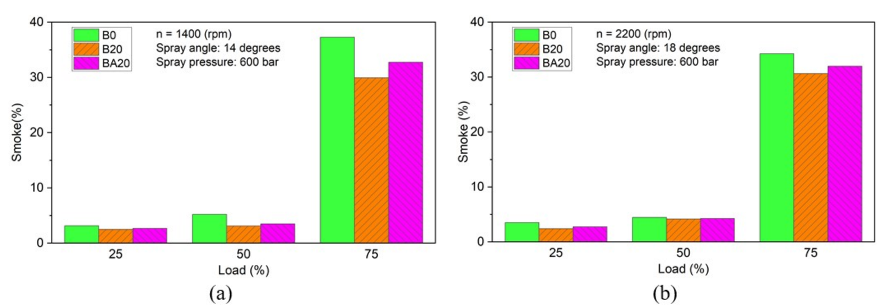

Fig.-8: Smoke Emission Graph According to Load at (a) Speed 1400 rpm and (b) Speed 2200 rpm

Biodiesel fuel has a higher Cetane value and additional oxygen in the fuel, making the firing process run smoothly, thus increasing the fire temperature. High burning temperatures make the fuel oxygen process better reduce smoke.[19] At each specific load mode, the black smoke component of the B0 is the largest and the smallest BA20. The BA20 is larger than the B20. The average reduction value of smoke emissions from biodiesel fuel is 21.56% with B20 and 15.47% with BA20, respectively, compared to B0 use, as stated in Fig.-8(a) and Fig.-8(b). Meanwhile, the emissions of the B20 smoke are smaller than the corresponding value of the BA20 at the speed n = 1400 (rpm) and n = 2200 (rpm), which are 9.65% and 6.95%. The larger viscosity of the BA20 explains this, so the inferior misting quality increases the ability to produce black smoke.

CONCLUSION

Economic, technical, and engine emission features depend on the origin of biodiesel. Biodiesel is produced from different sources with different physical and chemical properties, affecting the engine differently. The impact of two biodiesel fuels with different sources for capacity, BSFC, and emissions from diesel engines have been studied. Based on theoretical and test results, the following conclusions can be drawn: When using a mixture of biodiesel fuel from fried oil-frying, the engine power is reduced compared to fuel from fish fat due to lower heat treatment. When the engine runs the fuel of B20, B20A, the emissions decrease, corresponding to B0: with CO, respectively 15.39% and 19.50% respectively; With non-burning HC corresponding to 7.33% and 11.06% and the amount of soot emissions decreased by 21.56% and 15.47%; While NO_x emissions increased, equivalent to 6.86% and 4.31% respectively. On the other hand, there are giant CO, HC, and NO_x emissions than the corresponding value of the BA20 at n = 1400 (rpm) and n = 2200 (rpm): with CO is 4.51% and 5.36%; With HC is 4.67% and 3.46%; With NO_x is 2.39% and 2.34%. Meanwhile, the emissions of the B20 smoke are smaller than the corresponding value of the BA20 at the speed n = 1400 (rpm) and n = 2200 (rpm), which are 9.65% and 6.95%. The results also show that with different biodiesel fuel sources, the engine performance is not much different from that of a diesel fuel engine. On the other hand, biodiesel from waste fish fat recovered from the processing of Phile fish is very available in Vietnam, so it becomes a potential raw material for producing biodiesel.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing, and approved the final draft for publication. The research profile of the authors can be verified from their ORCID IDs, given below:

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