Effect of Temperature Variations of Corn (Maize) Oil Biodiesel on Torque Values and Thermal Efficiency of Diesel Engines

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ABSTRACT

The trend of consumption of hydrocarbon fuels in Indonesia, which is increasing every year, is not accompanied by the amount of production, which is decreasing. Alternative fuels to reduce dependence on hydrocarbon fuels. One form of alternative fuel is biodiesel, which is made from corn (maize) oil. Corn oil itself, if processed, can be an option for clean and environmentally friendly energy option and that is the main objective of this research is to determine the performance of biodiesel corn oil on diesel engines. The method used in this study is an experimental method where corn oil biodiesel is tested directly on a testing machine. The data from the test results will be used to find the torque and thermal efficiency values so that the engine performance values for each fuel variation can be identified. The results of the study obtained the engine performance value, namely the highest torque was on diesel oil fuel 4.57 N.m. The highest thermal efficiency value achieved at the B30 fuel sample at a temperature of 60 °C with the thermal efficiency of 17.4%. With these results, it can be concluded that engine performance with corn oil fuel can be used as an alternative fuel to replace hydrocarbon fuel.

Keywords: *Biodiesel, corn (maize) oil, temperature, thermal efficiency, torque value*

I. Introduction

Indonesia ranks 14th as a country with the level of consumption of fossil fuels in the world, with a total consumption of 1,470,000 barrels per day, while Indonesia's total oil production is 692,000 barrels per day [1]. According to a source from the Minister of Energy and Mineral Resources of Indonesia, Indonesia's oil reserves will only last for the next 9.5 years [2]. This has prompted the government to encourage research on environmentally friendly fuels such as biodiesel. Biodiesel is an environmentally friendly fuel source that can be an alternative to fossil fuels [3]. As a country with a tropical climate, Indonesia makes its soil fertile for various kinds of plants, one of which is corn, which can be processed into corn oil biodiesel. Indonesia's corn production data for 2020 reaches 22,500,000 tons [4], while the total world corn oil production is 3,189,137 tons, and Indonesia is capable of producing around 7,417 tons [5].

Various kinds of research related to biodiesel have been carried out, some of which is the production of biodiesel from waste cocking oil (WCO), whose research results state that the use of WCO biodiesel does not harm engine performance [6]. Studies of the potential of algae [7] and the potential of animal oil to become biodiesel indicate that animal oil with a mixture of up to B60 can provide a good thermal efficiency value for the engine as well as

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a low emission value compared to fossil fuels [8]. Biodiesel production from pome (palm oil milf effluent) results good engine performance values compared to diesel fuel [9]. The research that uses corn oil (maize) also gives good performance values for diesel engines [10]. Research states that one tonne of corn kernels contains as much as 0.5 to 0.6 sugar, which can be converted into bioethanol, a clean raw material for biodiesel production [11]. All of these studies show that biodiesel can be used as an alternative fuel that is environmentally friendly, renewable, low in emissions, and able to answer concerns about the oil crisis that is already in sight.

The viscosity of biodiesel fuel is its primary characteristic worth emphasizing. A study shows that the viscosity of biodiesel is higher than that of diesel fuel. The viscosity of diesel fuel is in the range of 2.5 – 3.2 cSt at 40 °C, while biodiesel is 1.3 – 6 cSt [12]. Another study states that the viscosity value of biodiesel, especially Palm Oil Mill Effluent (POME), is 4.98 cSt higher than the viscosity of diesel fuel, namely 1.8 – 4.1 cSt, which affects the value of engine performance [13]. The more biodiesel added to diesel fuel will also increase the viscosity of the fuel. The high viscosity makes the fuel transfer pump work harder, and the fuel pick-up process will not be perfect. To make the engine not work harder, the fuel viscosity must remain within the ASTM standards D445 [14]. The viscosity of biodiesel can be reduced by increasing the temperature of the fuel [14] so that biodiesel safe to apply to the engine.

In terms of engine performance, biodiesel can provide good performance, but that does not mean that biodiesel is a perfect and flawless fuel. In a study that tested the effect of using biodiesel on diesel engines used in fishing boats, the torque and power generated by engines with biodiesel fuel (B30) are slightly lower when compared to diesel fuel. In addition, the use of B30 makes the properties of changing engine lubricating oil. The results of the study stated that iron and aluminum metal content was found in the lubricating oil at 0.7% and 19.8%, respectively. Chromium content was also found in the same sample. It also found cases of loosened piston rings and journal bearings experiencing wear [15]. The International Maritime Organization (IMO), an agency under the auspices of the United Nations, has set a target of reducing world carbon emissions by 40% in 2030 and 70% in 2050 [16]. By looking at the facts about the urgent need for new energy to replace hydrocarbon fuels and efforts to make the environment cleaner from bad pollution, the main purpose of this research is to test the performance of biodiesel corn oil directly on diesel engines.

II. Material and Methods

The method used in this research is an experimental method of testing fuel samples directly on the engine. Similar research has also been carried out by converting waste cooking oil (WCO) into biodiesel, the results of which also provide good performance value for the engine, especially in terms of saving fuel consumption by around 45% [17]. Corn oil samples were prepared in three variations with turpentine oil, namely 30%, 50%, and 70%. The results obtained were that at full load, corn oil was able to provide a greater thermal efficiency value of 15% compared to using 100% hydrocarbon fuel [18]. The fuel samples used were pure diesel, B30 with a temperature variation of 50 °C, and B30 with a temperature variation of 60 °C. After the density and viscosity values of the fuel are known, then proceed to the next stage, namely testing on a test machine. B30 fuel with two temperature variations was tested on diesel engines. The data taken during engine testing includes voltage, current, fuel consumption, and time of fuel consumption.

The specifications of the diesel engines used in this study can be seen in Table 1.

Table 1. The specifications of engine [9],[10].

Engine Model	Yanmar TF 75/85 Series
Type of Engine	TF 85MH
No of Cylinder	1 Cylinder 4 Stroke
Displacement	493 cc
Continuous Power	7.5 Kw/2200 rpm
Compression Ratio	1:18
Specific Fuel Consumption (SFC)	171 gr/HP h
Volume per injection	0.07 mL

Engine tests were carried out on direct diesel engines with engine specifications according to Table 1 with variations of pure diesel fuel (without biodiesel mixture), B30 with a temperature variation of 50 °C, and B30 with a temperature variation of 60 °C. Data collection was carried out in testing diesel motors, which aims to determine the performance of diesel motors. The data taken during the trial included voltage, current and time values. This test uses 20 ml of fuel for each variation, starting from setting the engine speed to 1000 rpm, with a variety of loading from 1000 watts to maximum load (4000 watts). After the data was obtained in the form of current, voltage, and time values, calculations were carried out based on the formula previously described to obtain values for power (kW), specific fuel consumption (kg.kW.h), torque (N.m), and thermal efficiency (%). The machine testing scheme can be seen in Figure 1.

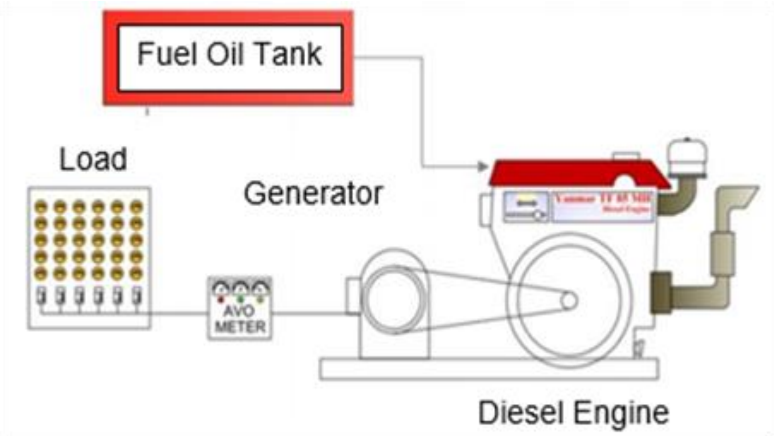

Fig. 1. Schematic diagram of experimental engine set-up [19]

III. Results and Discussions

The research stage that must be carried out was to make a fuel sample that will be tested on a diesel engine. The sample is B30, a mixture of 30% corn oil and 70% diesel fuel. These samples were then made in two temperature variations, namely 50^0 C and 60^0 C. The two fuel samples were then tested for their viscosity and density values. Table 2 shows the density and viscosity values of biodiesel fuel according to PT Pertamina.

Table 2. Biodiesel specifications [20]

Characteristic	Unit	Min value	Max value	Methods
Density	gr/ml	0.815	0.88	ASTM D4052/1298
Viscosity	Cst	2	5	ASTM D445

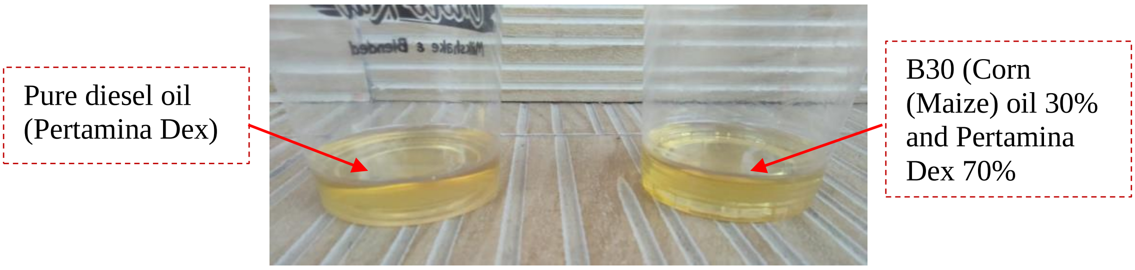

Fig. 2. Fuel samples. a) Pure diesel oil, b) Corn (Maize) oil B30

a) b) c)

Fig. 3. a) B30 temperature measurement, b) testing the density of B30 using a pycnometer, c) testing the viscosity of B30 using a viscometer

Figure 2 shows two fuel samples, namely pure diesel oil and B30, while Figure 3a shows the process of measuring the temperature of the previously heated B30 fuel. Figure 3b shows the process of testing the density of the fuel using a pycnometer, and Figure 3c shows the process of testing the viscosity of the B30 fuel sample with a temperature variation of 50 °C and 60 °C. The results of testing the viscosity and density of the fuel can be seen in Table 3, which shows that the density and viscosity values of B30 fuel are not included in the standard fuel determined by PT Pertamina, according to Table 2.

Table 3. Density and viscosity of B30 biodiesel with temperature variations of 50 °C and 60 °C.

Pertamina Standard Biosolar (B30)				Biodiesel Corn Oil B30		
Characteristic	Unit	Min Value	Max Value	Temp.(°C)	Result	Methods
Density	gr/ml	0.815	0.88	50	0.92	ASTM D4052/1298
				60	0.91	
Viscosity	Cst	2	5	50	6.2	ASTM D445
				60	5.8	

1. Engine Performance Testing

The engine test is carried out to determine the resulting engine performance value based on the variation of the fuel used. The data obtained in the engine testing process were used to find the value of power, torque, SFC, and engine thermal efficiency. Table 4 shows the engine test result data.

Table 4. Engine test result data in four load conditions

Fuel	Load (watt)	V (Volt)	A (Ampere)	Time (s)	V (Volt)	A (Ampere)	Time (s)	V (Volt)	A (Ampere)	Time (s)
		750 rpm			1000 rpm			1250 rpm		
Diesel Oil	1000	72.2	3.26	308	112.4	3.37	211	138.1	3.47	165
	2000	65.5	3.29	224	88.6	3.42	166	78.9	3.48	146
	3000	53.5	3.45	210	63.2	3.68	162	58.3	4.17	144
	4000	40.4	4.5	190	51.8	4.94	155	50.1	5.88	138
B30 50 °C	1000	72.8	2.03	348	115.7	2.43	260	149.5	2.95	233
	2000	68.5	2.68	302	104.6	2.75	205	94.7	3.24	209
	3000	59.7	3.02	298	75.7	3.07	165	65.2	4.32	162
	4000	45.9	3.68	280	60	3.68	141	54.4	4.34	140
B30 60 °C	1000	66.5	3.18	357	114.2	2.76	232	140	2.97	166
	2000	62	3.22	322	88.6	3.46	220	88.2	3.52	155
	3000	54.5	4	267	66.5	3.86	214	61	4.34	152
	4000	39.36	4.45	289	52.3	5.33	183	49.5	5.74	146

2. Performance Analysis of Diesel Engine

After testing the engine and obtaining the value of voltage, current, and time of fuel consumption, it can be determined the value of torque, SFC, and the value of thermal efficiency.

Comparative Analysis Between Torque and Load

One of the commonly used engine performance parameters is torque. The torque itself indicates the quality of the fuel. Whether it can provide a large torque value or not, the greater the torque affect the engine power. Figure 4 shows a graph of the ratio of torque to load with a variety of fuels, namely diesel without heating, B30 with a temperature of 50 °C, and B30 with a temperature of 60 °C at 750 rpm where the largest value is diesel fuel without heating at a load of 1000 watts with the torque value is 3.75 N.m. The smallest value is found in the B30 fuel with a temperature of 50 °C at a load of 1000 watts with a torque value of 2.36 N.m. Figure 4 shows the ratio of torque to load with a variety of fuels, namely diesel without heating, B30 with a temperature of 50 °C, and B30 with a temperature of 60 °C at 1000 rpm. The largest value is diesel fuel without heating at a load of 1000 watts with the torque value is 4.52 N.m, while the smallest value is found in the B30 fuel with a temperature of 50 °C at a load of 4000 watts with a torque value of 2.64 N.m. Figure 4 also shows the ratio of torque to load with various fuels, namely diesel without heating, B30 with a temperature of 50 °C, and B30 with a temperature of 60 °C at 1250 rpm, where the largest value is diesel fuel without heating at a load of 1000 watts with the torque value is 4.57 N.m, while the smallest value is found in the B30 fuel with a temperature of 50 °C at a load of 4000 watts with a torque value of 2.25 N.m.

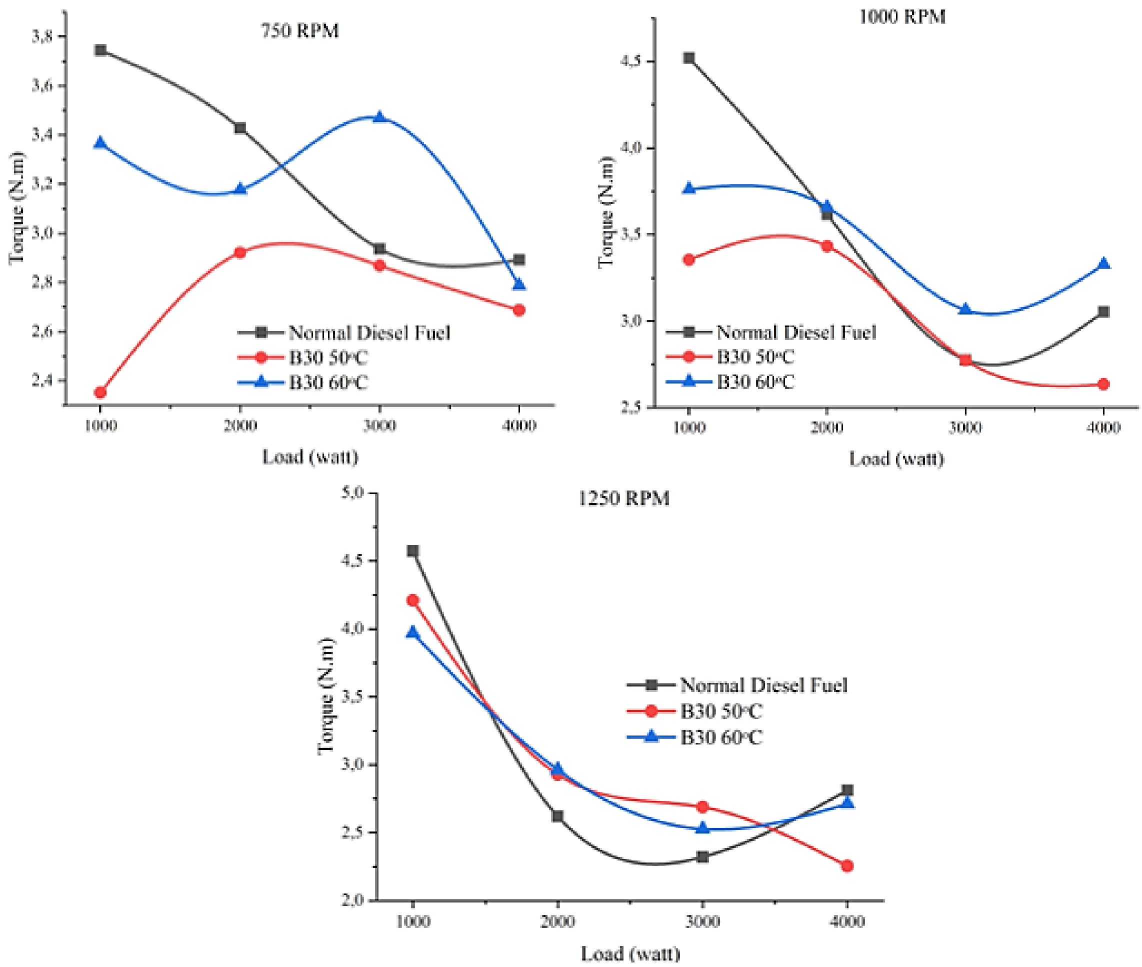

Fig. 4. Graph of torque vs load based on a variation of speed

Figure 4 shows the lowest average torque value found in the B30 fuel variation with a temperature of 50 °C at 750 rpm and 1000 rpm, so the power generated is also quite low. However, at 1250 rpm, the torque value has increased at a load of 1000 watts to 3000 watts. The average highest torque value is found on pure diesel fuel without heating at 750 rpm, 1000 rpm, and 1250 rpm at minimum load. Then, the B30 fuel with a temperature of 60 °C produces the highest torque value at 1000 rpm at maximum load. This affects the power generated is greater.

Comparative Analysis of Thermal Efficiency vs Power

Figure 5 shows the comparison of thermal efficiency to the load with a variety of fuels, namely diesel without heating, B30 with a temperature of 50 °C, and B30 with a temperature of 60 °C at 750 rpm where the largest value is found in the B30 fuel with a temperature of 60 °C at a load of 1000 watts with a thermal efficiency value of 0.128%. The smallest value is found in diesel fuel without heating at a load of 4000 watts with a thermal efficiency value of 0.058%.

Figure 5 shows the comparison of thermal efficiency to the load with a variety of fuels, namely diesel without heating, B30 with a temperature of 50 °C, and B30 with a temperature of 60 °C at 1000 rpm, where the largest value is found in diesel fuel without heating at a load of 1000 watts with a thermal efficiency value of 13.5%, while the smallest value is found in the B30 fuel with a temperature of 50 °C at a load of 4000 watts with a thermal efficiency value of 5.3%. It also shows the comparison of thermal efficiency to load with a variety of fuels, namely diesel without heating, B30 with a temperature of 50 °C, and B30 with a temperature of 60 °C at 1250 rpm. The largest value is found in the B30 fuel with a temperature of 50 °C at a load of 1000 watts with a thermal efficiency value of 17.4%, while the smallest value is found in the B30 fuel with a temperature of 50 °C at a load of 4000 watts with a thermal efficiency value of 5.6%.

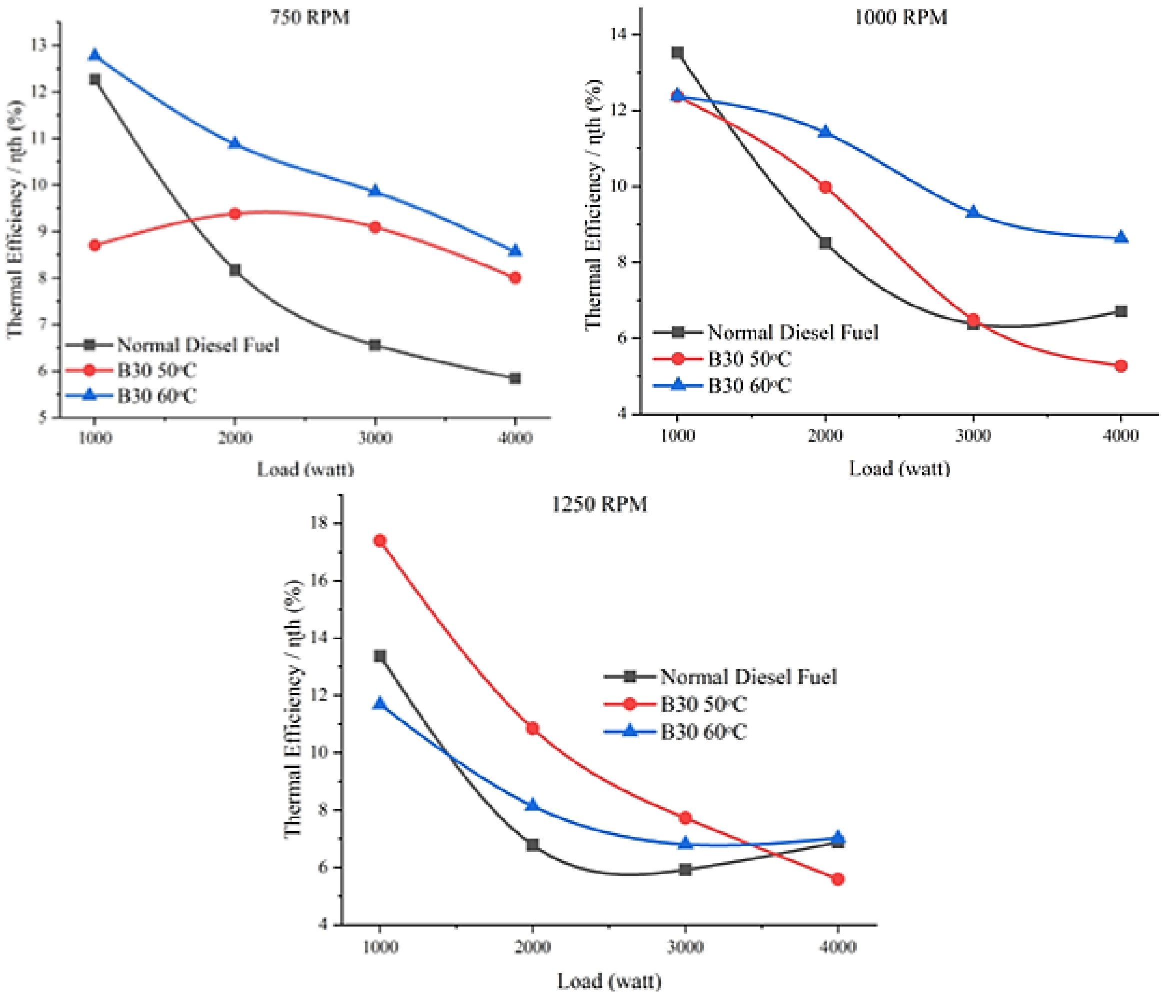

Fig. 5. Graph of thermal efficiency vs load based on a variation of speed

IV. Conclusions

The results of this study indicate that with variations in the mixture of diesel oil and corn oil (Maize) fuel, it can be used as an alternative fuel to reduce dependence on hydrocarbon fuels. Variations in temperature between B30 at 50 °C and 60 °C affects the viscosity and density values of the fuel. The higher the fuel temperature, the more values and density increase. B30 fuel at 50 °C and 60 °C have the viscosity value of 6.2 cSt and 5.8 cSt, respectively. The density of B30 at 50 °C and 60 °C are 0.92 gr/ml and 0.91 gr/ml, respectively. The performance value on the B30 at 60 °C indicates the highest torque of 4.75 N.m, and a thermal efficiency value of 17.4% is obtained.

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References

[1] S. Widi, "Indonesia's Oil Consumption Up 5.22% in 2021," 2022. https://dataindonesia.id/sektor-riil/detail/konsumsi-minyak-indonesia-147-juta-barel-per-hari-pada-2021 (accessed Feb. 18, 2023).

[2] "Kementerian ESDM RI - Media Center - News Archives - Indonesia's Oil Reserves to Last 9.5 Years and Gas 19,9 Years, Says Energy Minister." https://www.esdm.go.id/en/media-center/news-archives/indonesias-oil-reserves-to-last-95-years-and-gas-199-years-says-energy-minister (accessed Feb. 18, 2023).

[3] M. Manzanera, M. Molina-Munoz, and J. Gonzalez-Lopez, "Biodiesel: An Alternative Fuel," *Recent Pat. Biotechnol.*, vol. 2, no. 1, pp. 25–34, 2008, doi: 10.2174/187220808783330929.

[4] S. Widi, "Corn Production in Indonesia Reaches 22.5 million Tons in 2020," 2022. https://dataindonesia.id/sektor-riil/detail/produksi-jagung-indonesia-capai-225-juta-ton-pada-2020 (accessed Feb. 18, 2023).

[5] "Produksi Minyak Jagung Dunia menurut Negara - AtlasBig.com," 2022. https://www.atlasbig.com/id/negara-dengan-produksi-minyak-jagung (accessed Feb. 18, 2023).

[6] C. Adhikesavan, D. Ganesh, and V. Charles Augustin, "Effect of quality of waste cooking oil on the properties of biodiesel, engine performance and emissions," *Clean. Chem. Eng.*, vol. 4, no. December 2021, p. 100070, 2022, doi: 10.1016/j.clce.2022.100070.

[7] Azeez, N. A. Azeez, S. Oyelami, O. B. Ologunye, and S. A. Adedigba *et al.*, "Biodiesel potentials of microalgal strains isolated from fresh water environment," *Environ. Challenges*, vol. 5, no. August, p. 100367, 2021, doi: 10.1016/j.envc.2021.100367.

[8] G. A. C. Jayaseelan, A. Anderson, M. K. Poduva, and P. V. Sudheesh *et al.*, "Synthesis and performances characteristics of biodiesel from animal fat," *Mater. Today Proc.*, vol. 45, pp. 6053–6056, 2020, doi: 10.1016/j.matpr.2020.10.002.

[9] Suardi, M. Purwanto, A. Y. Kyaw, and W. Setiawan *et al.*, "Biodiesel Production from POME (Palm Oil Mill Effluent) and Effects on Diesel Engine Perfor- mance," *Int. J. Mar. Eng. Innov. Res.*, vol. 7, no. 4, pp. 292–299, 2022, doi: 10.12962/j25481479.v7i4.14492.

[10] S. S. Suardi, “Analisa Penggunaan Biodiesel Minyak Jagung Sebagai Campuran Bahan Bakar Alternatif Mesin Diesel,” *Inovtek Polbeng*, vol. 9, no. 2, p. 280, 2019, doi: 10.35314/ip.v9i2.1041.

[11] D. Balaji, T. M. Pillai, K. Gnanasekaran, and M. Balachandar *et al*., “Dataset for compression ignition engine fuelled with corn oil methyl ester biodiesel,” *Data Br.*, vol. 27, p. 104683, 2019, doi: 10.1016/j.dib.2019.104683.

[12] J. H. V. G. Mustafa E. Tat, “The Kinematic Viscosity of Biodiesel,” vol. 76, no. 12, pp. 1511–1513, 1999.

[13] E. Sutheerasak, W. Pirompugd, and S. Chuepeng, “The performance and emission of a generator-diesel engine fueled with palm oil methyl ester combined with carbureting biobutanol,” *Energy Reports*, vol. 9, pp. 210–218, 2023, doi: 10.1016/j.egyr.2022.12.109.

[14] X. Wang, Y. Ma, J. Huo, and J.Liu *et al.*, “Viscosity measurement and correlation research of one biodiesel component (methyl octanoate) with five 1-alcohols,” *Fuel*, vol. 324, no. PA, p. 124441, 2022, doi: 10.1016/j.fuel.2022.124441.

[15] E. Purwanto, B. Cahyono, P. Syamrahmadi, and A. Faisol, “Analysis of Diesel Engine Components Durability on Fishing Vessel Fueled with Biodiesel (B30),” *Int. J. Mar. Eng. Innov. Res.*, vol. 6, no. 3, pp. 204–209, 2021, doi: 10.12962/j25481479.v6i3.9451.

[16] International Maritime Organization “work to cut GHG emissions from ships.” https://www.imo.org/en/MediaCentre/HotTopics/Pages/Cutting-GHG-emissions.aspx (accessed Feb. 18, 2023).

[17] R. J. Ikhwani, Suardi, Alamsyah, and A. M. N. Arifuddin *et al.*, “Evaluation of Diesel Engine Performance Using Biodiesel from Cooking Oil Waste (WCO),” *J. Ris. Teknol. Pencegah. Pencemaran Ind.*, vol. 14, no. 1, pp. 29–39, 2023, doi: https://doi.org/10.21771/jrtppi.2023.v14.no1.p29-39.

[18] R. Sathyamurthy, D. Balaji,S. Gorjian, and S. J. Muthiya *et al.*, “Performance, combustion and emission characteristics of a DI-CI diesel engine fueled with corn oil methyl ester biodiesel blends,” *Sustain. Energy Technol. Assessments*, vol. 43, no. January, p. 100981, 2021, doi: 10.1016/j.seta.2020.100981.

[19] W. Setiawan. Suardi, M. Tasrief, and A. I. Wulandari *et al.*, “Testing the Inclination of an Industrial Diesel Engine Under Static Conditions According to the International Convention for the Safety of Life at Sea (SOLAS) Regulations,” *Int. J. Mar. Eng. Innov. Res.*, vol. 8, no. 1, pp. 8–15, 2023, doi: http://dx.doi.org/10.12962/j25481479.v8i1.15749.

[20] Pertamina, *Spesification Produk BBM, BBN & LPG*. 2020, p. 23.