Vol. 13, No. 1 (2024): 188 - 196
http://dx.doi.org/10.23960/jtep-l.v13i1.188-196
JURNAL TEKNIK PERTANIAN LAMPUNG
ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Experimental Study on The Performance Characteristics of 4 Stroke CI Engine using Biodiesel Blend from Coconut Oil

Suardi[1,✉], Feston Sandi Paribang[1], Wira Setiawan[1], Amalia Ika Wulandari[1], Muhammad Uswah Pawara[1], Andi Mursid Nugraha Arifuddin[1], Alamsyah[1]

[1] Department of Naval Architecture, Kalimantan Institute of Technology, Balikpapan, INDONESIA.

Article History:

Received : 07 August 2023
Revised : 30 August 2023
Accepted : 03 November 2023

Keywords:

Biodiesel,
Coconut oil,
Engine performance,
Fuel properties,
Transesterification.

Corresponding Author:
✉ suardi@lecturer.itk.ac.id

ABSTRACT

To address the challenges faced by the government in the realm of petroleum imports, a promising strategy was adopted in the utilization of biodegradable and renewable sources of biodiesel, such as coconut oil. This research employed two distinct methodologies: Transesterification for biodiesel synthesis and a comprehensive assessment of fuel properties. Subsequently, an experimental phase assessed biodiesel within an engine environment to analysis performance metrics. Results showed that B30 (30% coconut oil, 70% diesel oil) has density of 0.850 g/cm³, B50 (50% coconut oil) at 0.861 g/cm³, and B100 (Pure coconut oil) at 0.893 g/cm³. The values differed from regional standards. As per ASTM D6751, B30 has a viscosity of 2.31 cSt, B50 3.22 cSt, and B100 is 7.02 cSt. Engine performance revealed B50 with the highest torque at 11.787 Nm, while B0 (pure hydrocarbon diesel) has a thermal efficiency of 38%. B0's lowest SFC (Specific Fuel Consumption) is 261.12 g/kWh at 2000 watts load and 1000 rpm. Biodiesel coconut oil provided comparable power and torque (0.3% difference from B0) but consumed more fuel (21.6 % higher usage than B0).

1. INTRODUCTION

Indonesia occupies the forth position as the world largest population with an average population growth rate of 1,25% each year and by 2022 the total population is predicted to reach 275.8 million (BPS, 2023). The high rate of population growth has a significant impact on the rate of energy consumption, especially for hydrocarbon fuels (Muzayanah *et al*., 2022). When the Covid-19 pandemic hit the world, it harmed the world economy including in Indonesia, but on the other hand, limited community activities outside resulted in reduced fuel consumption which resulted in a drastic reduction in HC emissions in the environment (Hartono *et al*., 2021). Increased fuel consumption did not couple with the value of domestic fuel production so that since 2002 until now Indonesia has relied on oil imports to cover domestic shortages. The government also plans to implement decarbonization to achieve the Net Zero Emissions (NZE) target in 2060 (Rahman *et al*., 2023) so that the use of hydrocarbon fuels will be gradually reduced and replaced with clean and environmentally friendly fuels.

Biodiesel is a type of fuel derived from vegetable and animal oils, and can also be sourced from waste such as waste cooking oil which is biodegradable, non-toxic, contains a lot of oxygen, and is friendly to the environment (Parandi *et al*., 2022). Biodiesel is also known as a low-sulfur fuel which makes its emissions cleaner than hydrocarbon fuels (Kratzeisen & Müller, 2010; Tasrief *et al*., 2023). Fuels containing high sulfur will produce exhaust gas containing sulfates and biodiesel from vegetable oils has a lower exhaust gas pollutant value than hydrocarbon fuels.

High levels of carbon (OC), black carbon (EC/BC), ash, and heavy metals are a large contributor to emissions (Chu-Van *et al*., 2020). Many types of biodiesel have been studied, such as biodiesel from waste cooking oil (WCO) (Suanggana & Said, 2023; Suardi *et al*., 2023a; Desiyana *et al*., 2014; Sinaga *et al*., 2014), biodiesel from corn (maize) oil (Suardi *et al*., 2023b), biodiesel production from castor oil (Suardi *et al*., 2023c), biodiesel from algae (Azeez *et al*., 2021), and biodiesel from coconut oil (Pramitha *et al*., 2016). Almost all types of vegetable oils have been studied and are dominantly capable of being used as alternative fuels to substitute for hydrocarbon fuels.

One material that has the potential to be developed into biodiesel in Indonesia is coconut. Coconut oil has a relatively high content of saturated fatty acids, so it has a lower melting point and higher viscosity compared to some other sources of vegetable oil. This can help in better and more efficient combustion in diesel engines. Indonesia is among the largest coconut producers in ASEAN with a total production of 2.87 million tonnes in 2022 (BPS, 2023). Coconut oil has advantages over biodiesel from other vegetable oils, namely density and viscosity values , and is within the range recommended by ASTM D6751 (Shete *et al*., 2022). A study that tested coconut fatty acid distillate (CFAD) into biodiesel by mixing methanol into CFAD with a ratio of 10:1 was able to produce as much as 92% biodiesel and when tested on a machine it produced a reduced value of carbon monoxide, hydrocarbons, and smoke by 50% compared to diesel oil (Rajesh *et al*., 2021). Another study, namely the mixture of Hibiscus and Coconut oil biodiesel for the B20 blend variation, produced a good performance value for an engine with the highest thermal efficiency of 28% and lower HC and CO values compared to diesel oil (Farobie & Matsumura, 2017). The trend of increasing fuel consumption in Indonesia is always increasing while production is always decreasing so that the difference is covered by imports.

In light of the pronounced escalation in the hydrocarbon fuel subsidy burden and the escalating concern over rising fuel price, this study elucidates the imperative of delving into the latent potential of biodiesel derived from vegetable oils, with a particular focus on coconut oil, as an environmentally sustainable energy source poised to ameliorate these pressing concerns. The findings presented in this investigation furnish a comprehensive grasp of the biodiesel's inherent traits and its performance when synthesized via the transesterification process. The analytical outcomes affirm that biodiesel derived from coconut oil manifests distinctive attributes, rendering it a propitious candidate to supplant a substantial portion of conventional hydrocarbon fuels

2. METHODS

There were two stages used in this study, the transesterification method for making biodiesel and an experimental method for testing the performance of diesel engines after using biodiesel. The experimental method was the second stage after biodiesel has been made and blended with diesel oil with a variety of mixtures used. Similar research using vegetable oil has been tested in the laboratory, the engine was simulated in an uneven mounting condition and performance testing was carried out to determine the suitability of the fuel to be used in ship engines (Suardi *et al*., 2023a). Testing is carried out in several places such as the integrated laboratory of the ITK Kalimantan campus for testing engine and fuel properties, and the production of coconut oil is carried out in the Penajam area (center of coconut plantations in Setanjung).

The transesterification method is also known as the methanolysis process because it uses a catalyst (Methanol and NaOH) in the process of making biodiesel. The results of the transesterification process will produce biodiesel, sludge, glycerol, and alkaline wastewater (Farobie & Matsumura, 2017). The transesterification process can be seen in Figure 1. The initial stage of the research is to make coconut oil from coconuts that have been cleaned. The amount of coconut used is 20 seeds which are then grated and the grated results are mixed with 5 L of water to get thick coconut milk. This coconut milk is then cooked for 4 hours and pure coconut oil is obtained. The process for making coconut oil can be seen in Figure 2.

The transesterification process necessitates the involvement of a catalyst to effectively mitigate the elevated acid number within coconut oil. Through the catalytic mediation, a clear demarcation between glycerol and biodiesel constituents is attainable. The oil was preheated to a temperature of 75 °C using a hot pot equipped with a mixer. The next step was to make a catalyst using 200 ml of methanol and 5 grams of NaOH for one liter of biodiesel. The process of mixing methanol and NaOH took about 5-10 minutes depending on the grade of NaOH. The subsequent phase involved the amalgamation of the liquid catalyst with preheated biodiesel at a temperature of 75 °C. Given the temperature sensitivity

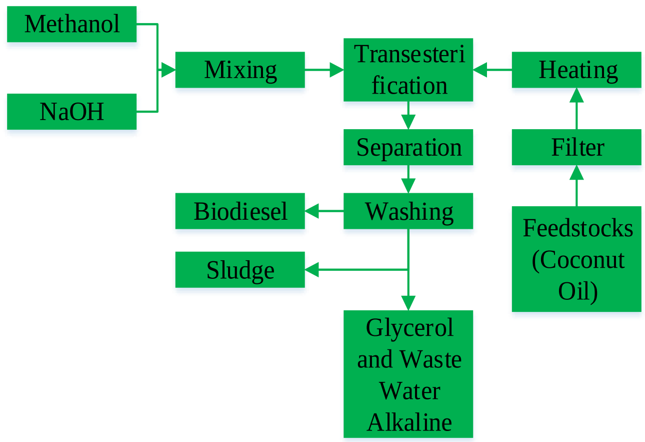

Figure. 1. Biodiesel production by transesterification method

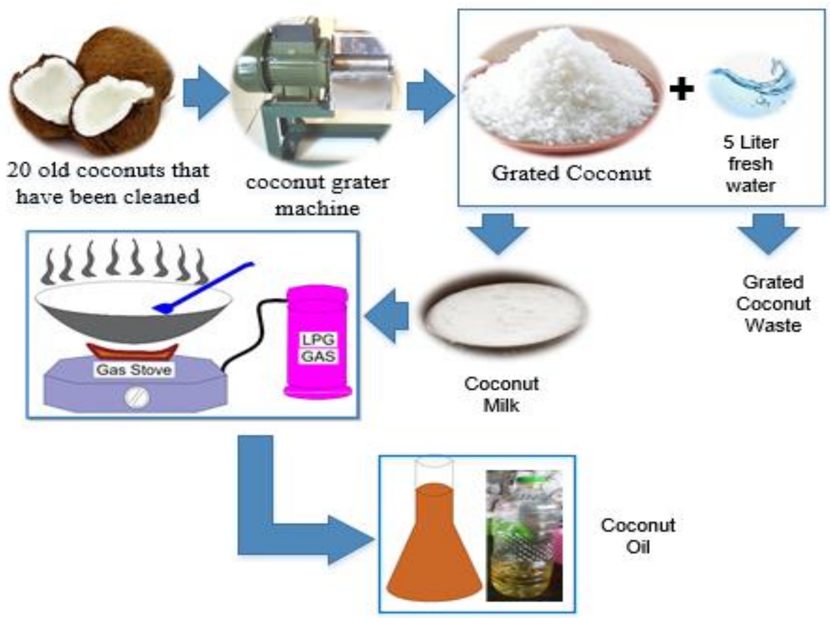

Figure. 2. Steps for making coconut oil

of methanol, which exhibits increased potency beyond 65 °C, the fuel temperature necessitates reduction to 50 °C prior to catalyst admixture. Following successful catalyst integration, the resultant fuel is subsequently conveyed to the washing tank for further processing. Then put the heated water into the washing tank and do it repeatedly until it is visually seen that the precipitate of the washing water looks clear or clean from the remaining glycerol. After it is seen that the washing water looks clear or clean, the last washing water is discarded and then pure biodiesel oil has been produced. The next step was to mix the fuel with various mixtures of B0, B30, and B50. B0 or pure diesel oil without biodiesel mixture, B30 or 70% diesel oil added 30% biodiesel, and B50 or 50% diesel oil added 50% biodiesel. After being mixed, the next step is to test the fuel properties. The properties of biodiesel tested are density, viscosity, and flash point. The assessment of engine performance subsequent to the application of biodiesel was executed on a 4-stroke diesel engine. The specification of the engine tested can be seen in Table 1.

Fuel testing scheme on the engine using a series of diesel engines, generators, voltage and current measuring devices, and indicator lights as a load, because in the test using three variations of rpm, a speed measuring device is also used to facilitate the data collection process. In full, the machine testing schematic diagram can be seen in Figure 3. Engine

Table 1. Combustion ignition (CI) engine specification

Item	Specification
Brand/Model	Yanmar TF 75/85 Series
Combustion Ignition (CI) Engine Type	TF 85 MH
No of (CI) Engine Cylinder	1 Cylinder 4 Stroke
Engine Displacement	493 cc
Countinuous (C) Power	7,5 kW/2200 rpm
Compression Ratio (RC)	1:18
Specific Fuel Consumption (SFC)	171 g/HP h

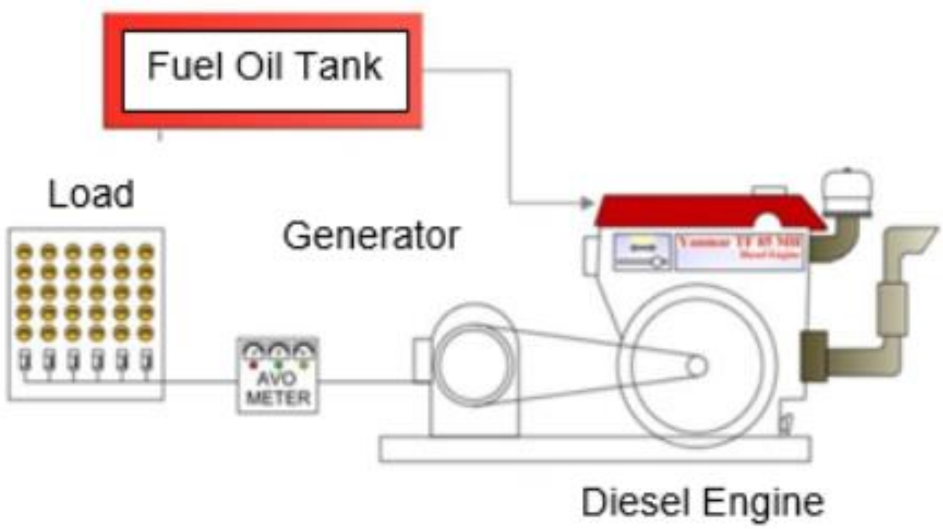

Figure 3. Engine schematic diagram (Suardi *et al*., 2023)

testing was carried out to obtain supporting data that will be processed to determine engine performance values such as engine torque, total fuel consumption, and thermal efficiency. When testing the engine, it will be recorded the amount of time the fuel consumption is used, then the light load will be turned on alternately to determine the increase in current and voltage from variations in fuel samples. The engine was tested in three rpm variations, namely 1000 rpm, 1200 rpm, and 1400 rpm, this was done because the effect of using high rpm would cause the incandescent lamp (load) to break down quickly. The next stage is when the data for time, amount of fuel, current, and voltage have been obtained, a performance value calculation will be carried out. The engine testing process was repeated three times for each fuel sample variation to obtain a more accurate value

3. RESULTS AND DISCUSSION

3.1 Properties of Biodiesel Coconut Oil

Testing of the fuel properties content is carried out to find out whether these blends of fuel have properties that are included in the standards set by the government. Fuel standards that are said to be good must meet at least two main criteria, namely providing good performance values for the engine such as good power and torque, good SFC, and thermal efficiency which is in the good category for the engine. For the second criterion, the fuel must have good properties such as density, viscosity, and flash point. Fuel properties determine engine performance because the fuel that has good properties will provide optimal combustion values for the engine (Pal *et al*., 2023). The value of biodiesel properties in biodiesel fuel samples B30, B50, and B100 can be seen in Figure 4.

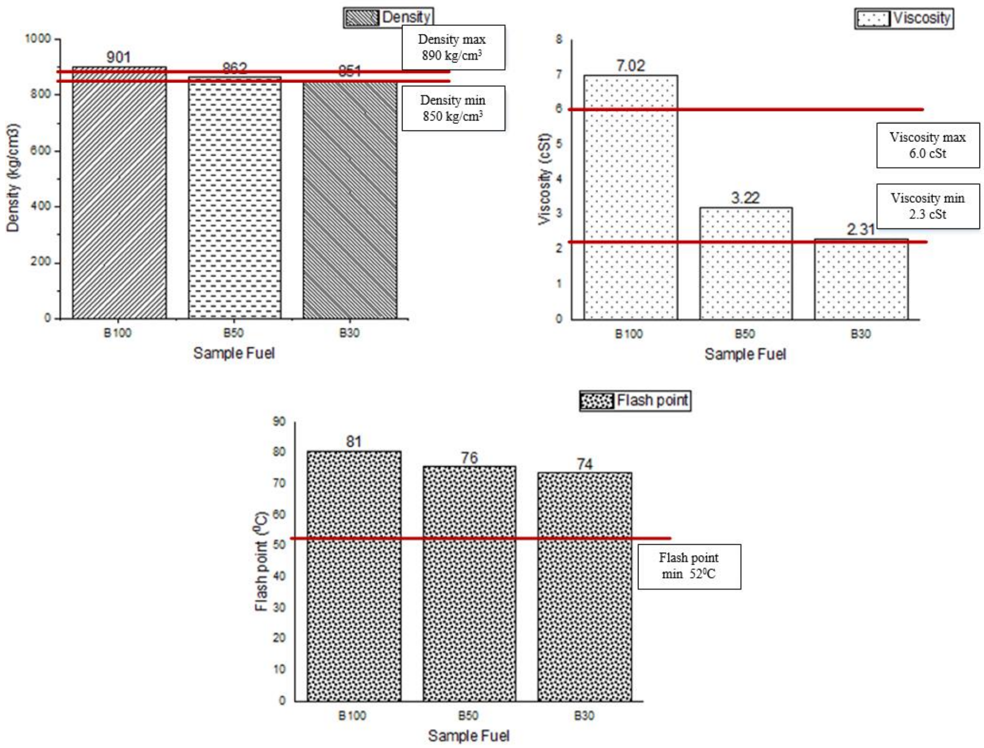

Figure. 4. Graph of biodiesel property values of density, viscosity, and flash point

3.2. Engine Performance

3.2.1. Torque vs load

Figure 5. a) shows a graph of the torque-to-load ratio with various fuels, namely B0, B30, and B50 at 1000 rpm rotation, where the largest value is found in the B50 fuel graph at 4000 watt of load with a torque value of 11.50 N.m, while the smallest value is found in the B0 fuel graph at a load of 1000 watt with a torque value of 3.90 N.m. Figure 5. b) below shows a graph of the ratio of torque to load with various fuels, namely B0, B30, and B50 at 1200 rpm rotation where the largest value is found in the fuel graph B0 at a load of 3000 watt with a torque value of 10.54 N.m, for the lowest value is found on the B0 fuel graph at a load of 1000 watt with a torque value of 4.99 N.m. Figure 5. c) shows a comparison graph between torque and load at 1400 rpm rotation with various fuels, namely B0, B30, and B50. Figure 4.19 below shows a graph of the ratio of torque to load with various fuels, namely B0, B30, and B50 at 1400 rpm rotation where the largest value is found in the fuel graph B0 at a load of 3000 watt with a torque value of 10.36 N.m, the lowest torque figure can be seen on the B0 fuel graph at a load of 1000 watt with a torque value of 4.94 N.m.

From the graph it can be concluded that B0 still provides good performance, especially torque on the engine, this is because biodiesel has a relatively higher water content compared to B0, and the density and viscosity values of the fuel increase as more and more mixtures of vegetable oils (coconut oil) are added.), this has the effect of reducing engine power which occurs because the process of fogging (injecting) the fuel is getting heavier due to the high viscosity.

3.2.2. Specific fuel consumtion (SFC) vs load

Figure 6. a) shows a graph of the comparison of SFC to load at 1000 rpm rotation with a variety of fuels, namely B0, B30, and B50 where the largest value is found in the B0 fuel graph at a load of 1000 watt with an SFC value of 546.77 g/kWh, the lowest SFC value is found in the B50 fuel graph at a load of 4000 watt with an SFC value of 261.70 g/kWh.

Figure 6. b) shows a graph of the comparison of SFC to load at 1200 rpm with a variety of fuels, namely B0, B30, and B50 where the largest value is found in the B50 fuel graph at 1000 watt of load with an SFC value of 425.25 g/kWh, different things are found at B0 where the lowest SFC value occurs at a load of 3000 watt 272.44 g/kWh. Figure 6. c)

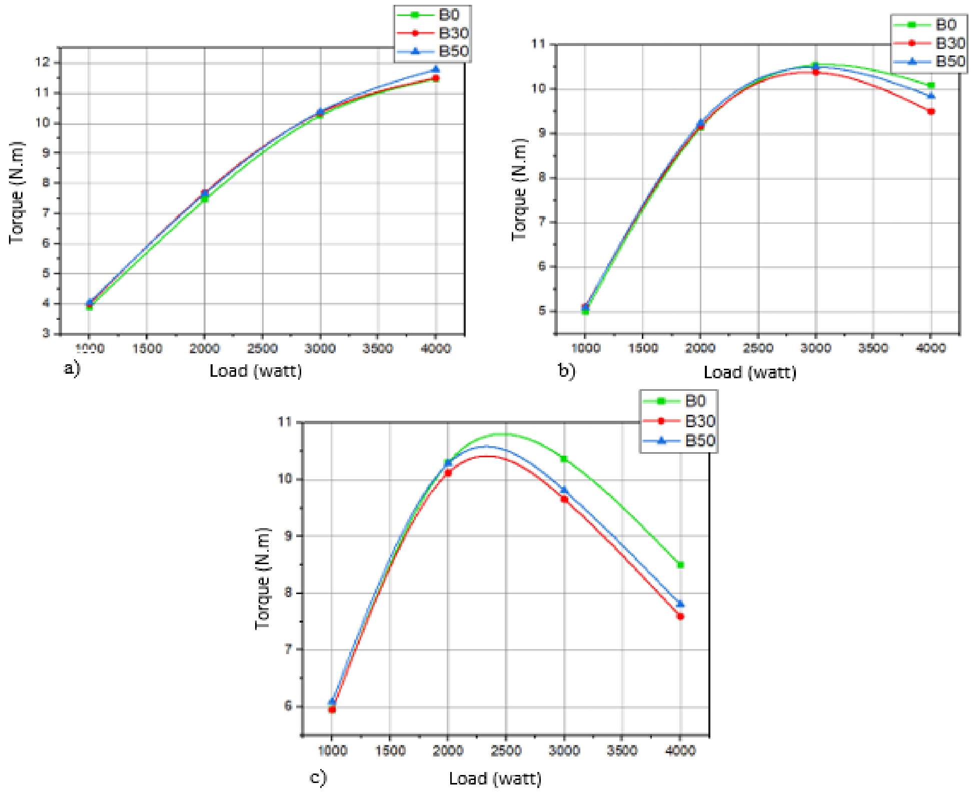

Figure. 5. Torque vs. load on variations in engine speed: a) 1000 rpm, b) 1200 rpm, c) 1400 rpm

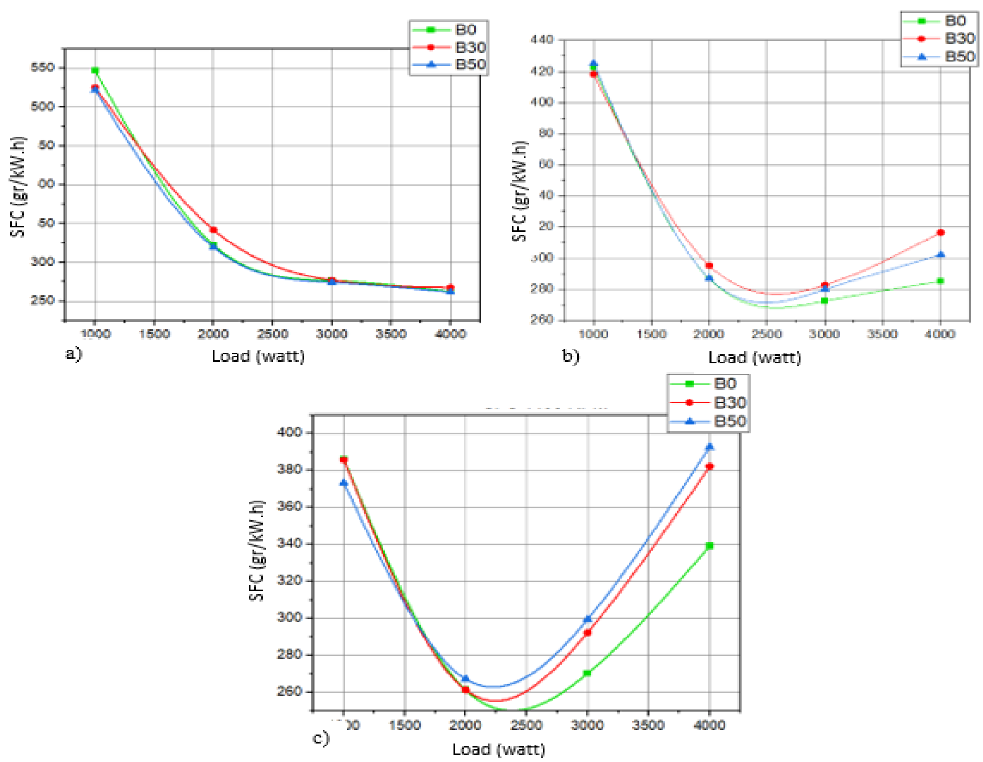

Figure. 6. SFC vs. load on variations in engine speed: a) 1000 rpm, b) 1200 rpm, c) 1400 rpm

shows a graph of the comparison of SFC to load at 1400 rpm with various fuels, namely B0, B30, and B50 where the largest value is found in the B50 fuel graph at 4000 watt of load with an SFC value of 392.78 g/kWh, B0 at a load of 2000 watt shows a low SFC value of 261.12 g/kWh.

The low calorific value of biodiesel causes the combustion process to be incomplete, to improve the combustion process, the fuel supply injected must be greater than the use of B0, on the other hand, the viscosity and density values of biodiesel are higher than those of B0 to achieve injection high fuel levels will cause the injector pump to work harder so that the effect will make the engine overheat faster. In the graph above it can be seen that B0 has lower fuel consumption at high engine speed. the use of biodiesel with a high vegetable oil content needs to be studied further about the effect on engine reliability.

3.2.3. Thermal efficiency vs load

Figure 7. a) shows a graph of the comparison of thermal efficiency to load at 1000 rpm rotation with various fuels, namely B0, B30, and B50 where the largest value is found in the B0 fuel graph at 4000 watt load with a thermal efficiency value of 38%, the lowest thermal efficiency value of 15% is in the B30 fuel sample with a load of 1000 watt. Figure 7. b) shows a graph of the comparison of thermal efficiency to load at 1200 rpm rotation with various fuels, namely B0, B30, and B50 where the largest value is found in the B0 fuel graph at 3000 watt load with a thermal efficiency value of 36%, the lowest thermal efficiency was also obtained on the B30 sample or similar to the 1000 rpm load above, even lower, namely 19% at 1000 watt load. Figure 7. c) shows a graph of the comparison of thermal efficiency to load at 1400 rpm rotation with various fuels, namely B0, B30, and B50 where the largest value is found in the B0 fuel graph at a load of 2000 watt with a thermal efficiency value of 38%.

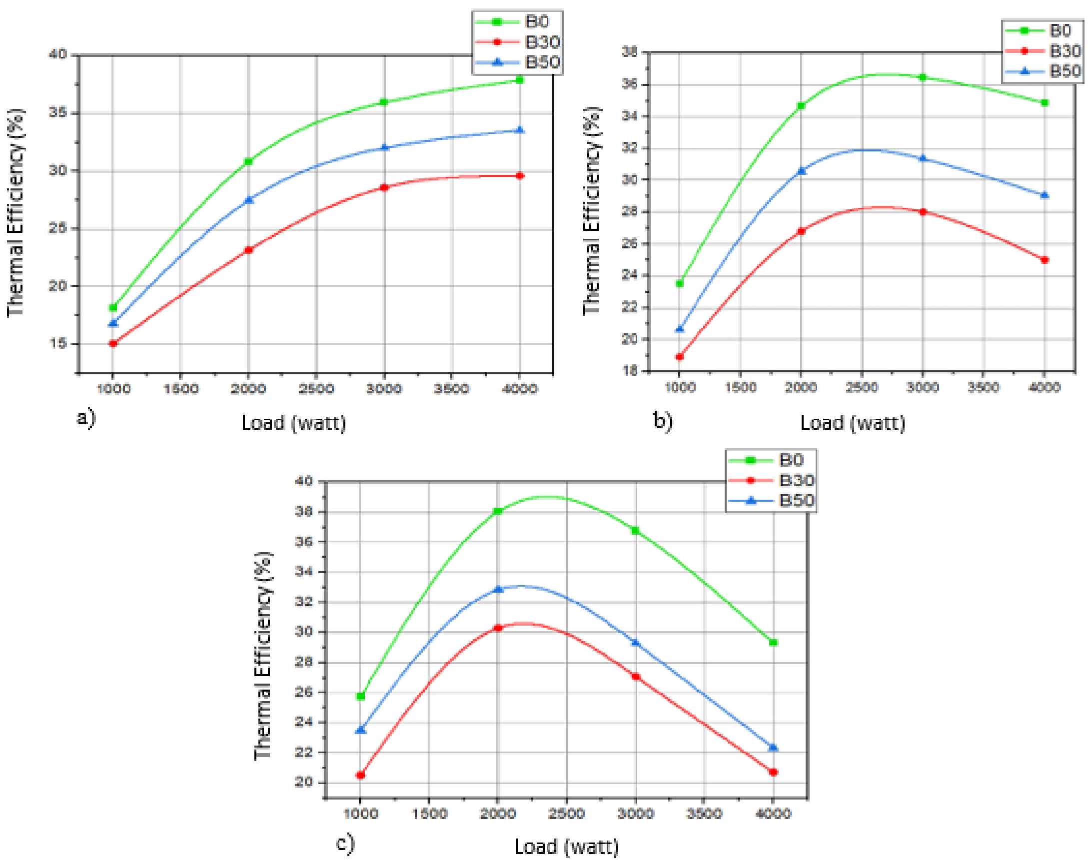

Figure. 7. Thermal efficiency vs. load on variations in engine speed:: a)   1000 rpm, b) 1200 rpm, c) 1400 rpm

From the graph, it can also be seen that B30 still provides a low thermal efficiency value of 21% higher than at 1000 and 1200 rpm with this efficiency value indicating that the higher the vegetable oil content in the fuel the lower the thermal efficiency value. The calorific value has a large effect on the thermal efficiency of the engine, the low calorific value also has an effect in the form of relatively low power. It is undeniable that adding more vegetable oil makes the injection and combustion performance of the engine more severe. But this, will have a big effect in terms of reducing dependence on petroleum which will run out.

4. CONCLUSIONS

The characteristic density value of coconut oil-derived biodiesel B30 and B50 stand at 0.850 g/cm^3 and 0.861 g/cm^3, respectively. It is notable that both these values align with the specifications outlined in ASTM D6751. Conversely, the density measurement for B100, denoting a density of 0.893 g/cm^3, deviates from the stipulations within ASTM D6751. Subsequent to rigorous testing, the viscosity values for B30 and B50 were determined to be 2.31 cSt and 3.22 cSt, respectively, adhering to the standards set forth by ASTM D6751. However, when evaluating B100, the recorded viscosity value of 7.02 cSt surpasses the established parameters delineated in ASTM D6751.

The performance of diesel engines using coconut oil biodiesel fuel is as the percentage of biodiesel increases, the torque performance, and thermal efficiency decrease; the highest torque value is found in B50 fuel at 1000 rpm rotation with a 4000-watt load worth 11.7874 N.m while the lowest torque value is found in B0 fuel at 1000 rpm rotation with a 1000 watt load worth 3.9057 N.m. The highest thermal efficiency value is found in B0 fuel at 1400 rpm rotation with a 2000-watt load worth 38% while the lowest thermal efficiency value is found in B30 fuel at 1000 rpm rotation with a 1000-watt load worth 15%. The highest SFC value is found in B0 fuel at 1000 rpm rotation at 1000 watt load worth 546.777 g/kWh, while the lowest SFC value is found in B0 fuel at 1400 rpm rotation at 2000 watt load worth 261.124 g/kWh.

REFERENCES

Azeez, N.A., Oyelami, S., Adekanmi, A.A., Ologunye, O.B., Adedigba, S.A., Akinola, O.J., & Adeduntan, A.S. (2021). Biodiesel potentials of microalgal strains isolated from fresh water environment. *Environmental Challenges*, ***5***, 100367. https://doi.org/10.1016/j.envc.2021.100367.

BPS (Badan Pusat Statistik). (2023). *Statistik Indonesia 2023 - Statistical Yearbook of Indonesia 2023*. Jakarta: Badan Pusat Statistik.

Chu-Van, T., Surawski, N., Ristovski, Z., Yuan, C.S., Stevanovic, S., Rahman, S.A., Hossain, F.M., Guo, Y., Rainey, T., & Brown, R.J. (2020). The effect of diesel fuel sulphur and vanadium on engine performance & emissions. *Fuel*, ***261***, 116437. https://doi.org/10.1016/j.fuel.2019.116437.

Desiyana, V., Haryanto, A., & Hidayati, S. (2014). Pengaruh rasio molar dan waktu reaksi terhadap hasil dan gelombang ultrasonik. *Jurnal Teknik Pertanian Lampung*, ***3***(1), 49–58.

Farobie, O., & Matsumura, Y. (2017). State of the art of biodiesel production under supercritical conditions. *Progress in Energy and Combustion Science*, ***63***, 173–203. https://doi.org/10.1016/j.pecs.2017.08.001.

Hartono, D., Yusuf, A.A., Hastuti, S.H., Saputri, N.K., & Syaifudin, N. (2021). Effect of COVID-19 on energy consumption and carbon dioxide emissions in Indonesia. *Sustainable Production and Consumption*, ***28***, 391–404. https://doi.org/10.1016/j.spc.2021.06.003.

Kratzeisen, M., & Müller, J. (2010). Influence of phosphorus content of coconut oil on deposit and performance of plant oil pressure stoves. *Renewable Energy*, ***35***(11), 2585–2589. https://doi.org/10.1016/j.renene.2010.04.001

Muzayanah, I.F.U., Lean, H.H., Hartono, D., Indraswari, K.D., & Partama, R. (2022). Population density and energy consumption: A study in Indonesian provinces. *Heliyon*, ***8***(9), 10634. https://doi.org/10.1016/j.heliyon.2022.e10634.

Pal, S., Kumar, A., Ali, M.A., Gupta, N.K., Pandey, S., Ghodkhe, P.K., Bhurat, S., Alam, T., Eldin, S.M., & Dobrota, D. (2023). Experimental evaluation of diesel blends mixed with municipal plastic waste pyrolysis oil on performance and emission characteristics of CI engine. *Case Studies in Thermal Engineering*, ***47***, 103074. https://doi.org/10.1016/j.csite.2023.103074.

Parandi, E., Safaripour, M., Abdellattif, M.H., Saidi, M., Bozorgian, A., Nodeh, H.R., & Rezania, S. (2022). Biodiesel production from waste cooking oil using a novel biocatalyst of lipase enzyme immobilized magnetic nanocomposite. *Fuel*, ***313***, 123057. https://doi.org/10.1016/j.fuel.2021.123057.

Pramitha, R.I., Haryanto, A., & Triyono, S. (2016). Pengaruh perbandingan molar dan durasi reaksi terhadap rendemen biodiesel dari minyak kelapa (coconut oil). *Jurnal Teknik Pertanian Lampung*, ***5***(3), 157–166.

Rahman, A., Richards, R., Dargusch, P., & Wadley, D. (2023). Pathways to reduce Indonesia's dependence on oil and achieve longer-term decarbonization. *Renewable Energy*, ***202***, 1305–1323. https://doi.org/10.1016/j.renene.2022.11.051.

Rajesh, K., Natarajan, M.P., Devan, P.K., & Ponnuvel, S. (2021). Coconut fatty acid distillate as novel feedstock for biodiesel production and its characterization as a fuel for diesel engine. *Renewable Energy*, ***164***, 1424–1435. https://doi.org/10.1016/j.renene.2020.10.082.

Shete, M., Deshpande, H., & Bhosale, S. (2022). Experimental evaluation of performance and emission characteristics of different blends of ecofriendly hibiscus and coconut oil mixture on CRDI engine. *Sustainable Energy Technologies and Assessments*, ***54***, 102853. https://doi.org/10.1016/j.seta. 2022.102853

Sinaga, S.V., Haryanto, A., & Triyono, S. (2014). Pengaruh suhu dan waktu reaksi pada pembuatan biodiesel dari minyak jelantah. *Jurnal Teknik Pertanian Lampung*, ***3***(1), 27–34.

Suanggana, D., & Said, B. (2023). Biodiesel potentials of waste cooking oil (WCO): Production, content of fuel properties, and effects on engine performance. *The International Journal of Marine Engineering Innovation and Research* (*IJMEIR*), ***8***(2), 213–221. http://dx.doi.org/10.12962/j25481479.v8i2.16679

Suardi, S., Setiawan, W., Nugraha, A.M., Alamsyah, A., & Ikhwani, R.J. (2023a). Evaluation of diesel engine performance using biodiesel from cooking oil waste (WCO). *Jurnal Riset Teknologi Pencegahan Pencemaran Industri*, ***14***(1), 29–39. https://doi.org/10.21771/jrtppi.2023.v14.no1.p29-39

Suardi, S., Ikhwani, R.J., & Aulia, A.P.R. (2023b). Effect of temperature variations of corn (maize) oil biodiesel on torque values and thermal efficiency of diesel engines. *Journal of Mechanical Engineering Science and Technology* (*JMEST*), *7*(1), 87–95. https://doi.org/10.17977/um016v7i12023p087

Suardi, S., Alamsyah, A., Nugraha, A.M., & Pawara, M.U. (2023c). Experimental analysis of castor oil and diesel oil mixtures in a 4-stroke compression combustion. *International Journal of Mechanical Engineering Technologies and Applications* (*MECHTA*), ***4***(5), 167–176. https://doi.org/10.21776/MECHTA.2023.004.02.6

Tasrief, M., Nurcholik, S.D., Wulandari, A.I., & Setiawan, W. (2023). 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. *International Journal of Marine Engineering Innovation and Research*, ***8***(1), 8–15. http://dx.doi.org/10.12962/j25481479.v8i1.15749