Jurnal Pendidikan Kimia (JPKIM)
p-ISSN: 2085-3653| e-ISSN: 2549-3116
https://jurnal.unimed.ac.id/2012/index.php/jpk/index

OPEN ACCESS
10.24114/jpkim.v16i2.62374
J. Pendidik. Kim 2024, 16(2), 176– 184

Original Research Article

Synthesis and characteristics rubber seed oil bioadditive from Sumatera Utara as low pour point of CPO biodiesel

Misdawati - *https://orcid.org/0000-0002-4225-1655*
Department of Mechanical Engineering, Universitas Al Washliyah, Medan 20147, Indonesia

Siswadi - *https://orcid.org/0000-0002-0873-2922*
Department of Mechanical Engineering, Universitas Singaperbangsa, Karawang 41361, Indonesia

Muhammad Said Siregar - *https://orcid.org/0000-0001-6871-0947*
Department of Agricultural Product Technology, Universitas Muhammdiyah Sumatera Utara, Medan 20226, Indonesia

Corresponding authors: Misdawati (e-Mail: misdawatipiliang@gmail.com)

Citation: Misdawati, M., Siswadi, S., & Siregar, M.S. (2024). Synthesis and characteristics rubber seed oil bioadditive from Sumatera Utara as low pour point of CPO biodiesel. Jurnal Pendidikan Kimia (JPKIM), 16(2), 176 – 184. https://doi.org/10.24114/jpkim.v16i2.62374

ARTICLE INFO

Keywords:
Bioadditive;
CPO;
Fatty Acid;
Linolenic acid;
Rubber seed oil

History:
♦Received - 05 August 2024
♦Revised - 25 August 2024
♦Accepted - 26 August 2024

ABSTRACT

One of the drawbacks of Crude Palm Oil (CPO) biodiesel is that it has high pour point which causes disadvantages in it's use. North Sumatra is the second largest rubber producer in Indonesia, the use of rubber seeds as a bioadditive to reduce the pour point of CPO biodiesel is one of the right steps. The synthesis of rubber seed oil bioadditives is carried out in two processes; esterification process and transesterification process. This research aims to reduce the pour point of CPO biodiesel by mixing it with bioadditive of rubber seed oil. This study evaluated the effect of composition to find the best combination of biodiesel ratios in the mixture. The research results show that the greater the proportion of bioadditive rubber seed oil, the lower the pour point of the mixed biodiesel. Biodiesel with a low pour point is obtained at 10°C from mixing CPO biodiesel with bioadditive rubber seed oil at a composition of 75:25 and the optimal pour point is -7°C. Performance testing is carried out to differentiate fuel properties and fuel performance. The results show that B15 fuel produces the best performance at a maximum engine speed of 3000 rpm. In this round, a maximum power of 1.5708 kW was obtained, the lowest specific fuel consumption was 517.52 gr/kWh, thermal efficiency was 18.77%; the smallest CO content was 2.808%; HC 185 rpm; CO_2 5.28%; NOx 4 ppm.

Introduction

Fossil fuels, especially petroleum, are still the main energy consumption, even though world petroleum reserves are limited and are believed to be increasingly in crisis, plus petroleum is a non-renewable energy source. This concern has raised attention to the use of vegetable oil as an alternative fuel. Research on alternative fuels to replace fossil fuels continues to be carried out (Alptekin and Canakci, 2009; Ayu et al., 2019). The parameters for the success of this alternative fuel are low exhaust emissions (NOx, SOx, CO_2, and CO) and meeting specifications.

According to SNI and ASTM D6751, vegetable oil is an alternative that can be used as raw material for making biodiesel. Vegetable oil is oil that comes from plants. Vegetable oil can be processed into biodiesel because it contains fatty acids (triglycerides) (Balasubramanian et al., 2021; Hadiyanto et al., 2020). Triglycerides are converted into methyl/ethyl esters through the transesterification process. Methyl esters are a component of biodiesel.

A pour point lowering additive is a material added to biodiesel with a high pour point to lower the pour point of the biodiesel according to usage requirements. So far, the existing additives generally come from petroleum derivatives which are made synthetically and are relatively expensive and cannot be renewed. Rubber plants in North Sumatra are superior plantation crops besides oil palm plants (Kalam and Masjuki, 2008; Wicakso et al., 2019; Kaniapan et al., 2021). Rubber plantation farming is spread throughout almost all districts.

The rubber seed oil content is 45-50% with the rubber seed oil composition consisting of saturated fatty acids; 8.7% stearic acid, 10.2% palmitic acid, and unsaturated fatty acids; oleic acid 24.6%; linoleic acid 39.6%; 16.3% linolenic acid (Pandiangan et al., 2019; Wahyono et al., 2022), the high content of unsaturated fatty acids causes the pour point of rubber seed oil to be low so that it can be synthesized into a bioadditive to lower the pour point of CPO biodiesel (Misdawati et al., 2024). Apart from the abundance of raw materials for making this additive, rubber seeds can be renewed and are environmentally friendly, making the by-product of rubber plantations more economically valuable.

Current sources of chemical raw materials and energy are still dominated by the use of petroleum. This source is believed to be increasingly in crisis. Therefore, the use of vegetable oil is cleaner because it does not contain sulfur and nitrogen, especially as the source of vegetable oil is abundant and is a by-product of rubber plantations which has not been utilized optimally (Ge et al., 2020; Franta, 2021; Hariyanto et al., 2021). Indonesia as the largest producer of CPO and rubber in North Sumatra has the potential to develop rubber seed oil bioadditives where the shortage of CPO biodiesel can be covered by rubber seed oil bioadditives (Misdawati et al., 2013; Adam et al., 2017; Mahlia et al., 2020). Rubber seed oil is a non-food oil so its use will not disrupt the stability of food oil (Boonnoun et al., 2019; Kushayadi et al., 2020; AVSL et al., 2021).

Methods

Materials

The main material used in this research is rubber seeds obtained from the People's Rubber Plantation in Langkat Regency, North Sumatra., CPO was obtained from the Medan Palm Oil Processing refinery, methanol, KO, NaOH., H_3P, n hexane, sulfuric acid p (pa), anhydrous sodium sulfate, n-hexane, Benzene was obtained from E'Merck with a grade of p.a and distilled water was purchased from a chemical shop.

The equipment used is a three-neck flask, ball cooler, thermometer, glass beake., separating funnel, magnetic stirrer, rotary evaporator, thermometer, and glassware to determine physicochemical characteristics such as Iodine number, saponification number., etc., as well as analysis of free glycerol and total glycerol levels. U tube to measure the pour point. The instruments used are Gas Chromatography and FT-IR Spectrometer.

General Procedure

The synthesis of rubber seed oil bioadditives is carried out in two processes, this is because rubber seed oil has free fatty acids (FFA) that are high > 2% (Ramadhas et al., 2005). For the Esterification process, 500 grams of rubber seed oil is added into the reactor, stirred at the desired speed, heated in a controlled manner, and stirred continuously at a temperature of 60 - 65°C. Then the H_2SO_4 p catalyst is added as much as 0.5% of the weight of the rubber seed oil. In methanol solvent (methanol: rubber seed oil 6: 1 mol). The mixture was continuously heated while refluxed at 65°C for 2 hours. The solvent was evaporated using a rotary evaporator. The bottom layer is removed and the top layer is further processed for the transesterification process.

The transesterification process is carried out at various ratio levels, desired stirrer speed, temperature, rubber seed oil/methanol mole ratio, and 1% KOH catalyst amount, the stopwatch is turned on and the reaction time is maintained for 90 minutes of reaction time. After the reaction time is reached, the reaction is stopped. The solvent was evaporated using a rotary evaporator, the bottom layer was discarded, and the top layer was extracted with n-hexane then washed until it was free of glycerol with distilled water several times until there were no more white precipitates. Any remaining water is removed by adding anhydrous sodium sulfate. All reactions were carried out twice. The volume of methyl ester (bioadditive) obtained was measured. A characteristic test was carried out on the results obtained based on the ASTM D6751 method. Functional group analysis using an FT-IR spectrometer and fatty acid composition using GC.

The synthesis of rubber seed oil bioadditives is carried out in two processes, esterification, and transesterification, this is because rubber seed oil has a high level of free fatty acids (FFA) > 2%. The transesterification process is carried out after the esterification process (reducing the free fatty acid content ≤ 2) at various ratio levels, desired stirrer speed, temperature, rubber seed oil/methanol mole ratio, and 1% KOH catalyst amount. After the reaction time is reached, the reaction is stopped. A characteristic test was carried out on the results obtained based on the ASTM D6751 method. The characterization tests carried out are acid number, iodine number, water content, pour point, density, viscosity, flash point, monoglyceride, diglyceride, triglyceride, free glycerol, total glycerol, and cetane number.

Mixing (blending) CPO biodiesel with rubber seed oil biodiesel aims to obtain a low pour point. In various compositions, CPO biodiesel is put into a lidded Erlenmeyer flask, then rubber seed oil bioadditive is added (at a composition of 5% v/v), and stirred with a magnetic stirrer for 10 minutes. The same thing is done for compositions of 10%, 15%, 20% and 25%.

Results and Discussion

After conducting research according to ASTM D6751 standards, the results of the analysis of the characteristics of bioadditive rubber Seed Oil and CPO biodiesel were obtained as follows in Table 1. The effect of ratio adding to bioadditive rubber seed oil to CPO biodiesel on pour point can be seen in Table 2.

Table 1. ASTM D6751 test results

Parameter	Biodiesel CPO	Bioadditives Rubber Seed Oil
Kadar Ester % berat	98.06%	98.81%
Monogliserida % berat	0.636%	0.430
Digliserida % berat	0.120%	0.220
Trigliserida % berat	0.016%	0.014
Gliserol Bebas % berat	0.015%	0.014
Total Gliserol % berat	0.085%	0.050
Water content % vol	0.065%	0.115%
Bil.Acid mg KOH/g	0.330	0.240
Bil.Iodium mg I_2/g	53.44	136.72
Setana Number	62	46.45
Pour Point °C	15	-13
Density at 40°C g/ml	0.887	0.880
Viscosity at 40^0C CSt	4.797	4.840
Flash point °C	171.5	170

Table 2. Effect of ratio adding bioadditive rubber seed oil to CPO biodiesel on pour point

Biodiesel CPO/ Rubber Seed Oil	Pour Point
95 : 5	12.5
90 : 10	11
85 : 15	10
80 : 20	9
75 : 25	7.5
100% Rubber Seed Oil Bioadditive	-13
100% CPO Biodiesel	15

The greater the proportion of rubber seed oil bioadditives added to CPO biodiesel, the lower the pour point will be. From the research results listed in Table 1, it can be seen that the average decrease in the pour point of CPO biodiesel is 1oC for every 5% volume of rubber seed oil bioadditive added (95% CPO biodiesel). The pour point that meets ASTM D7651 requirements is obtained when adding 15% rubber seed oil bioadditive where the pour point obtained is 10^{o}C (minimum requirement of ASTM D6751). From Table 2 above, it can be seen that the decrease in the pour point of CPO biodiesel is a liner. Sarin et al. (2007), reported on their research mixing CPO biodiesel with jatropha oil biodiesel. The results of CPO biodiesel analysis using FT-IR spectroscopy to determine the functional groups of CPO biodiesel can be seen in Fig-1.

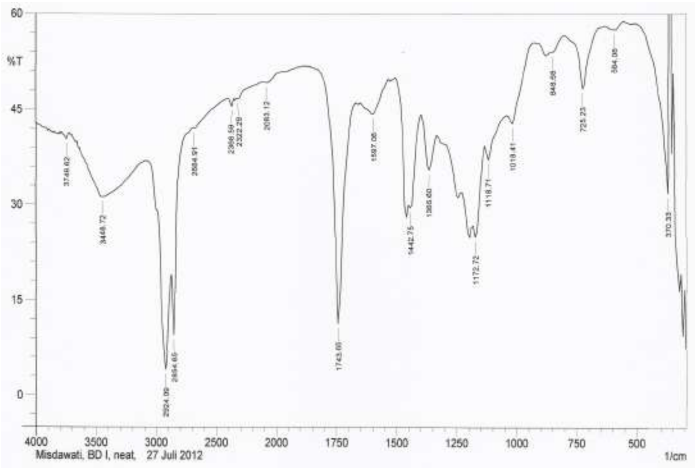

Fig-1. FT-IR spectra results for CPO biodiesel

From Fig-1. The FT-IR spectrum of CPO biodiesel can be seen that there are absorption peaks in the wave number area 2923.9 and 2854.5 cm-1, which is typical absorption from C-H sp3 stretching vibrations which are supported by C-H sp3 bending vibrations in the number area. Waves 1434 cm-1 - 1461.9 cm-1 and 720 cm-1. The presence of the C=O ester group is indicated by the appearance of absorption in the wave number area of 1743.5 cm-1 and this is supported by the absence of −OH carboxylic or −OH mono and diglyceride groups in the wave number area of 3500 cm-1 – 3300 cm-1. and the appearance of an absorption peak in the region 1172.6 cm-1 − 1195 cm-1 indicates the C − O −C vibration of methyl ester. The results of FT-IR spectroscopic analysis of bioadditive rubber seed oil can be seen in Fig-2.

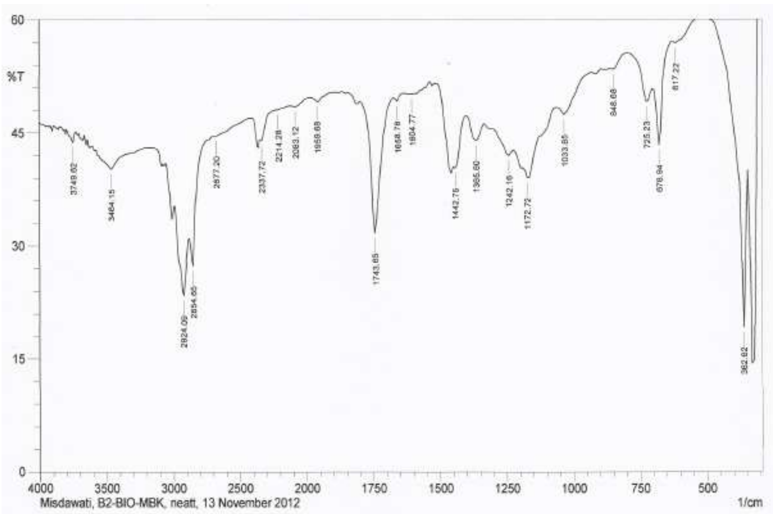

Fig-2. FT-IR spectra results of rubber seed oil bioadditives

The results of FT-IR spectroscopic analysis of rubber seed oil biodiesel (Fig-2) show that absorption peaks in the wave number areas 2924.09 and 2854.65 cm-1 are typical absorption from C-H sp3 stretching vibrations which are supported by C-H bending vibrations. sp3 in the wave number area 1442.75 cm-1 - 1357.89 cm-1 and 725.3 cm-1. The presence of the C=O ester group is indicated by the appearance of absorption in the wave number area of 1743.65 cm-1 and this is supported by the absence of –OH carboxylic or –OH mono and diglyceride groups in the wave number area of 3500 cm-1 - 3300 cm-1. and the appearance of an absorption peak in the area 1172.72 cm-1 – 1172.72 cm-1 indicates the C – O– C vibration of methyl ester. The composition of methyl ester fatty acid of rubber seed oil can be seen in Table 3.

Table 3. Methyl ester fatty acid composition rubber seed oil

Fatty acid	Fatty Acid Formula	Composition (wt%)
Myristat	C14:0	0.107
Palmitat	C16:0	9.104
Stearat	C18:0	10.251
Oleat	C18:1	25.378
Linoleat	C18:2	3.139
Linolenat	C18:3	16.421
Arakidat	C20	0.361
UNK		0.239

Cetane's Number

The cetane number is a measure of the ignition quality of biodiesel in its compressed state. The cetane number of biodiesel depends on the fatty acid composition of the methyl ester, methyl palmitate has a cetane number of 75, methyl stearate has a cetane number of 86 while methyl linoleate only reaches 33 (Knothe, 2007). The lower the cetane number, the lower the ignition quality because requires a higher ignition temperature. From the results of calculations using the formula used by (Mohibbeazam et al., 2005), the cetane number for CPO biodiesel is 62, and the cetane number for rubber seed oil biodiesel = 46 (Table 1).

The cetane number of CPO is higher, this is because the methyl ester fatty acid content is predominantly palmitic acid which is a saturated fatty acid that has a high cetane number and oleic acid (has one double bond). The cetane number of rubber seed oil bioadditives is lower because the majority of rubber seed oil bioadditive content is linoleic acid which has two double bonds, followed by oleic acid which has one double bond, and linolenic acid which has three double bonds, a more unsaturated fatty acid. This also greatly influences the low cetane number of candlenut oil biodiesel. It turns out that the double bonds most influence the high and low cetane number of the biodiesel produced, not the number of hydrocarbon chains. This is in line with Knothe (2007) explanation that the cetane number is influenced by the length of the carbon chain, but the double bonds influence the quality (cetane number) of a biodiesel more.

Pour Point

Determining the cloud point and pour point for CPO biodiesel and rubber seed oil, the results obtained respectively were the pour point which was 15°C and -9°C. The type of fatty acid in the oil greatly influences the physical and chemical characteristics of biodiesel. This is because these fatty acids will form esters or biodiesel itself. The influence of fatty acids on the characteristics of biodiesel is reviewed through a literature study. The composition of fatty acids in CPO as a result of gas chromatography analysis carried out shows that palmitic acid and oleic acid are the types of fatty acids that are mostly contained in CPO. So it can be said that the methyl ester formed is mostly methyl palmitate or methyl oleate. Palmitic acid and oleic acid are saturated and unsaturated fatty acids with high melting points, respectively 63°C and 16°C. Meanwhile, the melting point of methyl ester is 30.5°C and -20°C (Knothe, 2007). So biodiesel containing palmitate and oleic esters has a relatively high pour point which is suitable for use in tropical areas but cannot be used in subtropical areas. From Table 1 it can be seen that the pour point of CPO biodiesel is 15°C.

Meanwhile, in rubber seed oil bioadditives, oleic fatty acids and linoleic acid are the most dominant in content, so it can be said that the methyl esters formed are mostly methyl oleate, methyl linoleate, and metal linoleate. Oleic acid, linoleic acid, and linolenic acid are unsaturated fatty acids that have very low melting points, respectively 16°C, - 11°C, and -5°C. Meanwhile, the melting point of methyl oleate, methyl linoleate, and metal linoleate is -20°C, -35°C, and -52°C. So biodiesel containing oleic and linoleic esters has a very low pour point, suitable for use in cold regions. The results of the research carried out showed that the pour point of the rubber seed oil bioadditive was -9°C.

Biodiesel Ester Content

Ester content is the final result of the transesterification reaction which shows the success of the transesterification reaction (Demirbas, 2008). From Table 1. it can be seen that the CPO biodiesel ester content is 98.06%, and rubber seed oil biodiesel is 98.81%. These results indicate that the methanolysis reaction was carried out perfectly.

From the three ester levels obtained, it turns out that CPO oil biodiesel has the highest ester content. This confirms that the ester content obtained is closely related to the raw materials used. If the vegetable oil raw materials used are of good quality, it will also produce good biodiesel, proven by seed oil. It is rubber that has the highest level of purity where the free fatty acid content is the lowest after the esterification process.

Mono, Di and Triglyceride Levels

The levels of mono, di, and triglycerides contained in biodiesel indicate incomplete conversion of vegetable oil during the transesterification process (Demirbas, 2008). Chromatograms of mono, di, and triglyceride levels remaining in CPO biodiesel can be seen in the Appendix. From Table 1 it can be seen that between the two biodiesels the levels of mono, di, and triglycerides in rubber seed oil biodiesel are the lowest, this shows that the methanolysis reaction of rubber seed oil is better and the oil quality has the highest level of purity. The results obtained were still far below the maximum requirements of the ASTM 6751 biodiesel quality standard (maximum 0.8). The results above show that the methanolysis reaction carried out for all oils has run perfectly.

Total Gliserol

The total glycerol and free glycerol contained in the manufacture of CPO biodiesel, jatropha oil, and candlenut oil from the GC results can be seen in the Appendix. From Table 1, it can be seen that the total glycerol and free glycerol obtained from the two biodiesels are the rubber seed oil bioadditive that has the lowest total glycerol content, besides showing that the methanolysis reaction is running perfectly, it also shows that the rubber seed oil is the best quality. This is a parameter for the success of the purification of the biodiesel produced. So it is safe for diesel engines when used, there will be no deposit formation and the presence of OH groups which are aggressive towards non-ferrous metals and chrome mixtures (Monteiro et al., 2008).

Flash Point

Flash point is not directly related to machine performance, but is very important concerning security and safety, especially in handling and storage. A high flash point will make it easier to handle fuel because it does not need to be stored at low temperatures, whereas a flash point that is too low is dangerous because of the high risk of ignition which can ultimately cause a fire (Bhale et al., 2009).

From the research results in Table 1, it is found that the flash point of CPO biodiesel is higher between CPO biodiesel and rubber seed oil, meaning that CPO oil biodiesel is safer and easier to handle for storage and in the distribution process. Rubber seed oil biodiesel has a lower flash point so rubber seed oil biodiesel burns more easily under standard conditions (not in the combustion chamber of a diesel engine).

Water content

The presence of water has a great influence on biodiesel, a hydrolysis process can occur in biodiesel which will increase the acid number, lower the pH, and increase the corrosive properties. At low temperatures, water can encourage separation in pure biodiesel and the blending process. Meanwhile, sediment in biodiesel can clog and damage diesel engines (Knothe, 2007). From Table 1, it is known that the water content of rubber seed biodiesel is the lowest so the methanolysis reaction of rubber seed oil produces bioadditives (metal esters) with the highest ester content.

Acid Number

The acid number shows the total unsaturated bonds in the fatty acids present in biodiesel. From Table 1, it can be seen that the acid number of rubber seed oil biodiesel is lower. This shows that rubber seed oil biodiesel has the lowest levels of mineral acids and free fatty acids so the quality is better than CPO biodiesel. The maximum permitted acid number is ≤ 0.5 mg KOH/g fatty acid, if it exceeds it, it can become a catalyst for autocatalytic hydrolyphic reactions that break ester bonds, corrosion, and deposits in diesel engines (Knothe, 2007).

Iodine Number

The iodine number in biodiesel shows the level of unsaturation of the compounds that make up biodiesel. Unsaturated compounds can also reduce the stability of biodiesel to oxidation which can reduce lubrication quality. According to the biodiesel quality standard ASTM 6751, the maximum iodine number is 115. Besides that, the concentration of linolenic acid and acids that have 4 double bonds respectively must not exceed 12 and 1% (Mohibbeazam et al. 2005). A study conducted at Mercedes-Benz showed that biodiesel with an iodine number of more than 115 cannot be used in diesel vehicles because it causes excessive carbon deposits. However, other studies have concluded that iodine levels do not correlate significantly with cleanliness and deposit formation in the combustion chamber (Bukkarapu and Krishnasamy, 2022). From Table 4.3 it can be seen that the rubber seed oil biodiesel has the highest iodine value of 136.72, exceeding the biodiesel quality requirements. This is because candlenut biodiesel is the only one that has linolenic fatty acids which results in a high iodine number. Knothe (2007) reported that linolenic acid, which is a triple unsaturated fatty acid, has a relatively high iodine number, such as methyl linoleate, ethyl linoleate, propyl linoleate, and butyl linoleate, which have iodine numbers of 172.4 respectively; 164.5; 157.4 and 150.8 So the pure rubber seed oil bioadditive does not meet biodiesel quality standards, but can be used as a pour point lowering additive.

Specific Gravity

Specific gravity is closely related to the calorific value and power produced by a diesel engine per unit volume of biodiesel, specific gravity is related to viscosity. From Table 1 it can be seen that the higher specific gravity of CPO biodiesel between CPO biodiesel and rubber seed oil biodiesel causes the calories produced by CPO oil biodiesel to be higher and the lubrication properties are better between CPO biodiesel and rubber seed oil biodiesel.

Viscosity

This characteristic is very important because it affects the performance of injectors in diesel engines. Higher viscosity will cause the fuel to atomize into larger droplets with high momentum and have a tendency to collide with the relatively cooler cylinder walls. This causes flame extinction and increased deposits, fuel spray penetration, and engine emissions. On the other hand, fuel with low viscosity will produce a spray that is too fine and cannot penetrate further into the combustion cylinder, resulting in a fuel-rich zone area that causes soot formation (Bhale et al, 2009). From Table 1, it can be seen that the viscosity of rubber seed oil biodiesel is higher between CPO biodiesel and rubber seed oil, meaning that rubber seed oil bioadditive has the best lubricating properties than CPO biodiesel and rubber seed oil biodiesel.

The Effect of Mixing Ratio of CPO Biodiesel with Rubber Seed Oil Bioadditive on Pour Point

The pour point is determined using a U-blow flask pour point determination tool, 50 ml of the mixed biodiesel is put into a U-blow flask, and stored in a refrigerator (which reaches a temperature of – 80°C). Left for 24 hours, the U blow flask gauge is removed from the refrigerator, a temperature reading is taken as soon as the sample begins to flow, that is the pour point. The effect of the ratio addition of bioadditive rubber seed to pour point of biodiesel CPO can be seen in Table 4.

Table 4. Effect of bioadditive rubber seed oil addition ratio to pour point of CPO biodiesel

CPO Biodiesel/ Rubber Seed Oil	Pour Point
95: 5	13.5
90: 10	12
85 : 15	11
80 : 20	9
75 : 25	7
100% Rubber Seed Oil Bioadditive	-9
100% CPO Biodiesel	15

The greater the proportion of rubber seed oil bioadditives added to CPO biodiesel, the lower the pour point will be. From the research results listed in Table 4. It can be seen that the average decrease in the pour point of CPO biodiesel is 1°C for every 5% volume of rubber seed oil bioadditive added (95% CPO biodiesel). The pour point that meets the requirements of ASTM D7651 is obtained by adding 17% rubber seed oil bioadditive where the pour point obtained is 10°C (minimum requirement of ASTM D6751). From Table 4 it can be seen that the decrease in the pour point of CPO biodiesel is a liner. Sarin et al. (2007), reported on their research mixing CPO biodiesel with jatropha oil biodiesel.

The Effect of Blending Ratio of CPO Biodiesel with Bioadditive Rubber Seed Oil on the Cetane Number

Mixing (blending) CPO biodiesel with candlenut oil biodiesel aims to obtain biodiesel with a low pour point. A total of 45 ml of CPO biodiesel was put into an Erlenmeyer with a lid then added with 5 ml of candlenut oil, stirred with a magnetic stirrer for 10 minutes. The same thing is done for mixing (blending) biodiesel at compositions of 5%, 10%, 15%, 20%, and 25% v/v.

The pour point is determined using a U-blow flask pour point determination tool, 50 ml of the mixed biodiesel is put into a U-blow flask, and stored in a refrigerator (which reaches a temperature of – 80°C). Left for 24 hours, the U blow flask gauge is removed from the refrigerator, a temperature reading is taken as soon as the sample begins to flow, that is the pour point. The effect of the ratio addition of bioadditive rubber seed oil can be seen in Table 5.

Table 5. Effect of the ratio addition of bioadditive rubber seed oil into CPO biodiesel of cetane number

CPO Biodiesel/ Rubber Seed Oil	Cetane Numbers
95: 5	61.20
90: 10	60.44
85\ : 15	58.67
80 : 20	57.80
75 : 25	56.11
100% Rubber Seed Oil Bioadditive	4.45
100% CPO Biodiesel	62

The Engine Performance and Exhaust Gas Emissions

Engine performance testing needs to be carried out to differentiate fuel properties and fuel performance. In this study, the parameters measured were maximum rotation, specific fuel consumption, efficiency at 3000 rpm, thermal efficiency and exhaust emissions measured were CO_2, CO, and NOx.

To test the performance of CPO biodiesel (B100), it is mixed with rubber seed oil bioadditives at a certain level of ratio to obtain B5, B10, B15, and B20 (B5 is a mixture of 5% rubber seed oil bioadditive and 95% CPO biodiesel. As a comparison for the biodiesel that is sold at the Pertamina gas station. Diesel engine performance and exhaust emissions were compared with engines using Pertamina Biosolar, B100 CPO and B15. Engine performance test on three types of fuel using a Diesel I Cylinder TD 110 Type Robin Fuji DY 25 D motor. constant rotation 1400, 1800, 2200, 2600, 3000 rpm. The research results show that B15 fuel produces the best performance at a maximum rotation of 3000 rpm (Fig-3). At this rotation the maximum power is 1,5708 kW (Fig-4), the lowest specific fuel consumption is 517.52 gr. /kWh (Fig-5), thermal efficiency 18.77% (Fig-6), smallest CO content of 2.808% , HC 185 rpm, CO_2 5.28%, NOx 4 ppm.

From the results of the performance and exhaust emissions tests that have been carried out, from the graph above it can be seen that the average calorific value of B15 fuel is better than B100 CPO, this is because the fatty acid content in vegetable oil which is the raw material for biodiesel is slightly less stable. when compared to diesel, especially in terms of oxidation. Differences in raw materials cause the stability of one biodiesel to be different from another biodiesel depending on the number of double bonds in the carbon chain it contains (C=C). The greater the number of double bonds in the carbon chain, the greater the tendency to undergo oxidation. For example, C18: 3 which has three double bonds is three times more reactive to undergo oxidation than C18: 0 which does not have three double bonds. Biodiesel B100 CPO does not have triple bonds which makes rubber seed oil bioadditives more flammable than CPO biodiesel. From the operating temperature used, it can be seen that B15 also has a higher calorific value at low temperatures, this is because the pour point of the rubber seed oil bioadditive is lower than CPO biodiesel.

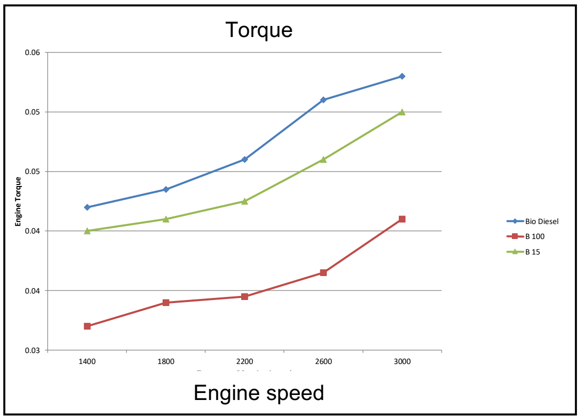

Fig-3 Engine speed vs torque

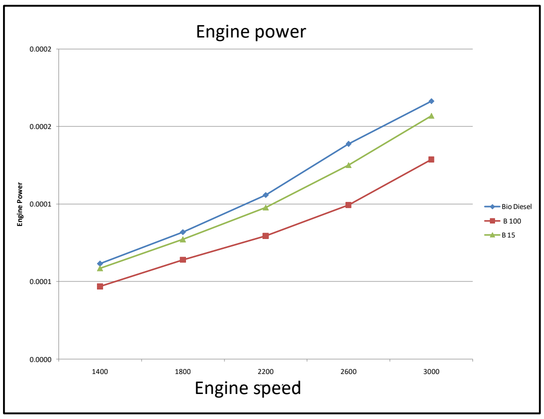

Fig-4. Engine Speed vs engine power

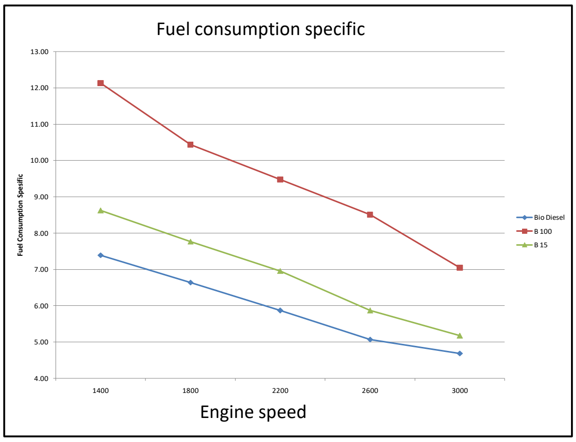

Fig-5. Engine speed vs fuel consumption

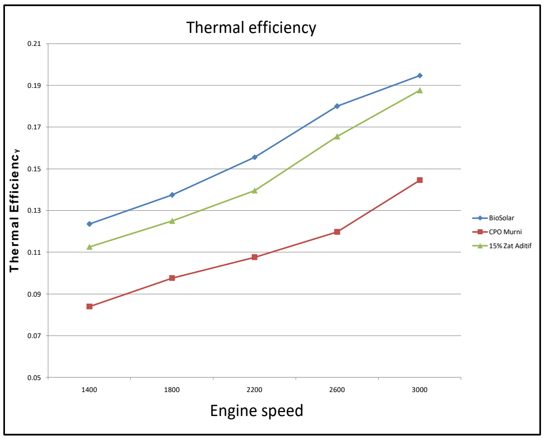

Fig-6. Engine speed vs thermal efficiency

The power produced by B15 is much higher than B100 CPO, approximately 18%, this is because B15 has triple bonds, even though B100 CPO has a higher cetane number than B15. The specific fuel consumption of B15 is less than that of B100 CPO by more than 26% at a maximum rotation of 3000 rpm. This is also due to the higher double bond content of B15, making it more flammable. Lapuerta has concluded that there is a difference in the need for additives, especially those that are rich in oxygen and dissolve completely in diesel/biodiesel oil so fuel consumption is more efficient. B15 is almost the same as biodiesel on the market (Pertamina gas stations).

The low consumption of B15 fuel automatically increases the thermal efficiency value (more than 4% higher than B100 CPO) because it is inversely proportional to specific fuel consumption. B15 is almost the same as diesel (biodiesel) sold at Pertamina gas stations. The use of B15 shows that the combustion properties and exhaust gas emissions are almost the same as diesel (Pertamina gas station biodiesel). From the performance and exhaust emission test results data, there is a distribution of emission data from three different types of fuel. B15 gas emissions are almost the same as B100 CPO, in diesel (biodiesel from Pertamina gas stations, some of which come from petroleum which has a different chemical composition.

Conclusion

Rubber seed oil bioadditive (B15) can be used as a pour point lowering additive for CPO biodiesel at low temperatures (≤ 10 0C). From the performance tests carried out, the best engine performance was obtained at 3000 rpm, at this speed the maximum power was 1,5708 kW, specific fuel consumption was 517.52 gr/kWh, thermal efficiency was 18.77%, CO content was 1.701%; CO_2 4.56%; NOx 2 ppm. If we compare it with CPO biodiesel, the overall performance of the rubber seed oil bioadditive (B15) is better, meaning that the addition of the rubber seed oil bioadditive further improves the performance of the user's engine. The average engine performance for the three is almost the same, although in terms of specific fuel consumption, it turns out that diesel (biodiesel from gas stations) is better. Considering that Indonesia has more than 40 types of vegetable oils that have the potential as raw materials for bioadditives, it is necessary to develop other non-edible vegetable oil bioadditives such as kapok seed oil, pongam, nyamplung as raw materials for making bioadditives to reduce the pour point of CPO biodiesel.

Conflict of Interests

The author declares that there is no conflict of interest in this research and manuscript.

Acknowledgment

Researchers would like to thank the validators who were willing to take the time to validate and provide valuable input. The researcher would also like to thank all participants, lecturers, laboratory heads and laboratory assistants who have contributed by providing feedback in this research.

References

Adam, I. K., Aziz, A. R. A., Heikal, M. R., & Yusup, S. (2017). Performance and Emission Analysis of Rubber Seed Methyl Ester and Antioxidant in a Multicylinder Diesel Engine. *Energy & Amp; Fuels*, 31(4), 4424–4435. https://doi.org/10.1021/acs.energyfuels.6b02994

Alptekin, E., & Canakci, M. (2009). Characterization of the key fuel properties of methyl ester–diesel fuel blends. *Fuel*, 88(1), 75–80. https://doi.org/10.1016/j.fuel.2008.05.023

Ayu, D., Aulyana, R., Astuti, E. W., Kusmiyati, K., & Hidayati, N. (2019). Catalytic Transesterification of Used Cooking Oil to Biodiesel: Effect of Oil-Methanol Molar Ratio and Reaction Time. *Automotive Experiences*, 2(3), 73–77. https://doi.org/10.31603/ae.v2i3.2991

Mohibbeazam, M., Waris, A., & Nahar, N. (2005). Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. *Biomass and Bioenergy*, 29(4), 293–302. https://doi.org/10.1016/j.biombioe.2005.05.001

Balasubramanian, D., Hoang, A. T., Papla Venugopal, I., Shanmugam, A., Gao, J., & Wongwuttanasatian, T. (2021). Numerical and experimental evaluation on the pooled effect of waste cooking oil biodiesel/diesel blends and exhaust gas recirculation in a twin-cylinder diesel engine. *Fuel*, 287, 119815. https://doi.org/10.1016/j.fuel.2020.119815

Bhale, P. V., Deshpande, N. V., & Thombre, S. B. (2009). Improving the low temperature properties of biodiesel fuel. *Renewable Energy*, 34(3), 794–800. https://doi.org/10.1016/j.renene.2008.04.037

Boonnoun, P., Shotipruk, A., Kanda, H., & Goto, M. (2018). Optimization of rubber seed oil extraction using liquefied dimethyl ether. *Chemical Engineering Communications*, 206(6), 746–753. https://doi.org/10.1080/00986445.2018.1522502

Bukkarapu, K. R., & Krishnasamy, A. (2022). A critical review on available models to predict engine fuel properties of biodiesel. *Renewable and Sustainable Energy Reviews*, 155, 111925. https://doi.org/10.1016/j.rser.2021.111925

Demirbas, A. (2008). Relationships derived from physical properties of vegetable oil and biodiesel fuels. *Fuel*, 87(8–9), 1743–1748. https://doi.org/10.1016/j.fuel.2007.08.007

Franta, B. (2021). Early oil industry disinformation on global warming. *Environmental Politics*, 30(4), 663–668. https://doi.org/10.1080/09644016.2020.1863703

Ge, J. C., Kim, H. Y., Yoon, S. K., & Choi, N. J. (2020). Optimization of palm oil biodiesel blends and engine operating parameters to improve performance and PM morphology in a common rail direct injection diesel engine. *Fuel*, 260, 116326. https://doi.org/10.1016/j.fuel.2019.116326

Hadiyanto, H., Aini, A. P., Widayat, W., Kusmiyati, K., Budiman, A., & Roesyadi, A. (2020). Multi-Feedstocks Biodiesel Production from Esterification of Calophyllum inophyllum Oil, Castor Oil, Palm Oil and Waste Cooking Oil. *International Journal of Renewable Energy Development*, 9(1), 119–123. https://doi.org/10.14710/ijred.9.1.119-123

Hariyanto, R. A. B., Firmansyah, R. A., Burhan, R. Y. P., & Zetra, Y. (2021). Synthesis of Bio-additive for Low Sulphur Diesel: Transesterification of Soybean Oil and Ethylene Glycol using K2CO3 Catalyst. *Automotive Experiences*, 4(1), 44–50. https://doi.org/10.31603/ae.4694

Kalam, M. A., & Masjuki, H. H. (2008). Testing palm biodiesel and NPAA additives to control NOx and CO while improving efficiency in diesel engines. *Biomass and Bioenergy*, 32(12), 1116–1122. https://doi.org/10.1016/j.biombioe.2008.02.009

Kaniapan, S., Hassan, S., Ya, H., Patma Nesan, K., & Azeem, M. (2021). The Utilisation of Palm Oil and Oil Palm Residues and the Related Challenges as a Sustainable Alternative in Biofuel, Bioenergy, and Transportation Sector: A Review. *Sustainability*, 13(6), 3110. https://doi.org/10.3390/su13063110

Knothe, G. (2007). Some aspects of biodiesel oxidative stability. *Fuel Processing Technology*, 88(7), 669–677. https://doi.org/10.1016/j.fuproc.2007.01.005

Kushayadi, A. G., Suprayudi, M. A., Jusadi, D., & Fauzi, I. A. (2019). Evaluation of rubber seed oil as lipid source in red tilapia (Oreochromis sp.) diet. *Aquaculture Research*, 51(1), 114–123. https://doi.org/10.1111/are.14352

Mahlia, T. M. I., Syazmi, Z. A. H. S., Mofijur, M., Abas, A. E. P., Bilad, M. R., Ong, H. C., & Silitonga, A. S. (2020). Patent landscape review on biodiesel production: Technology updates. *Renewable and Sustainable Energy Reviews*, 118, 109526. https://doi.org/10.1016/j.rser.2019.109526

Misdawati, M., Siswadi, S., Dina, S.F., 2024. Characteristic Analysis of Candlenut Oil Methyl Ester As an Alternative Bio Additive To Lower the Pour Point of Cpo 48–55. https://doi.org/10.35261/barometer.v9i1.10945

Misdawati, M., Nasution, M., & Syafiruddin, S. (2013). Synthesis and Characteristic Bioadditive of Rubber Seed Oil as Low Pour Point Biodiesel CPO. *In 3rd Syiah Kuala University Annual International Conference 2013*, p. 22-27.

Monteiro, M., Ambrozin, A., Liao, L., & Ferreira, A. (2008). Critical review on analytical methods for biodiesel characterization. *Talanta*, 77(2), 593–605. https://doi.org/10.1016/j.talanta.2008.07.001

Pandiangan, M., Kaban, J., Wirjosentono, B., & Silalahi, J. (2019). Analisis Kandungan Asam Lemak Omega 3 dan Omega 6 pada Minyak Ikan Mas (Cyprinus Carpio). *Talenta Conference Series: Science and Technology (ST)*, 2(1), 37–44. https://doi.org/10.32734/st.v2i1.309

AVSL, S. B., Subramaniapillai, N., Mohamed, M. S. B. K., & Narayanan, A. (2021). Effect of rubber seed oil biodiesel on engine performance and emission analysis. *Fuel*, 296, 120708. https://doi.org/10.1016/j.fuel.2021.120708

Sarin, R., Sharma, M., Sinharay, S., & Malhotra, R. K. (2007). Jatropha–Palm biodiesel blends: An optimum mix for Asia. *Fuel*, 86(10–11), 1365–1371. https://doi.org/10.1016/j.fuel.2006.11.040

Wahyono, Y., Hadiyanto, H., Budihardjo, M. A., Hariyono, Y., & Baihaqi, R. A. (2022). Multifeedstock Biodiesel Production from a Blend of Five Oils through Transesterification with Variation of Moles Ratio of Oil: Methanol. *International Journal of Technology*, 13(3), 606. https://doi.org/10.14716/ijtech.v13i3.4804

Wicakso, D. R., Najma, A. N., & Retnowati, D. A. (2019). Crude biodiesel synthesis from rubber seed oil. *Konversi*, 7(1), 21. https://doi.org/10.20527/k.v7i1.4872