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TEST OF BIODIESEL FROM USED COOKING OIL FROM DORMITORY X ON OPACITY AND EXHAUST EMISSIONS HC, CO AND CO^2

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Abstract: The current trend is the use of biodiesel as an alternative fuel, one alternative is used cooking oil. Not many Indonesian people are aware of the great potential for utilizing used cooking oil or commonly called cooking oil (waste vegetable oil or WVO, also known as waste cooking oil or WCO). The aim is to minimize pollution of used/used cooking oil waste in the surrounding environment as environmental conservation, to know the characteristics and quality requirements of used cooking oil/used cooking oil from dormitory X to become biodiesel according to SNI 04-7182-2015 standards, as well as the effect of blending biodiesel from cooking oil used/used cooking oil from dormitory X with PT Pertamina's Solar TBBM on opacity, performance and exhaust emissions of diesel engines. Test results for used cooking oil test criteria for smell, taste, visual color, water content, free fatty acids, acid number and peroxide value do not meet the quality standards of SNI 01-3741-2002, so they are not suitable for use or consumption again because they are toxic. The highest yield value is 81.33% and the lowest is 61.7%. Analysis of the FAME content was 98.18% and the remaining 0.72% glycerol. The highest content of methyl palmitate was 47.57% and the lowest content was 1.502% methyl myristate. Density test results were 815 – 880, viscosity were 2.3 – 6.0 cST, water content were 210,667 – 366,750, ASTM Copper Strip color test and copper blade corrosion were sequentially number 3 and class 1 A. The highest opacity value was achieved at 3000 rpm rotation . Emissions of hydrocarbons (HC) produce no HC on average. Carbon monoxide (CO) exhaust emissions produce an average of 0.05% by volume. Emission levels of CO2 in exhaust gas show an average of 0.2% by volume.

Keywords: Emissions, FAME, Opacity, Used Cooking Oil.

Abstrak: Trend yang berkembang saat ini adalah penggunaan biodiesel sebagai alternatif bahan bakar, salah satu alternatifnya adalah minyak goreng bekas. Tidak banyak masyarakat Indonesia yang mengetahui adanya potensi besar untuk pemanfaatan minyak goreng bekas atau yang biasa disebut minyak jelantah *(waste vegetable oil* atau WVO disebut juga *waste cooking oil* atau WCO dan *used cooking oil* atau UCO). Tujuan untuk meminimalkan pencemaran limbah minyak goreng bekas/jelantah di lingkungan sekitar sebagai konservasi lingkungan, mengetahui karakteristik dan syarat mutu dari minyak goreng bekas/minyak jelantah dari asrama X menjadi biodiesel sesuai standar SNI 04-7182-2015, serta pengaruh *blending* biodiesel dari minyak goreng bekas/minyak jelantah dari asrama X dengan Solar TBBM milik PT Pertamina terhadap opasitas, performa dan emisi gas buang mesin diesel. Hasil pengujian minyak jelantah kriteria uji bau, rasa, warna visual, kadar air, asam lemak bebas, bilangan asam dan bilangan peroksida sudah tidak memenuhi standar mutu SNI 01-3741-2002, sehingga tidak layak untuk pemakaian atau konsumsi kembali karena bersifat toksik. Nilai *yield* tertinggi sebesar 81.33% dan terendah sebesar 61.7%. Analisa kandungan FAME sebanyak 98.18% dan sisanya gliserol sebanyak 0.72%. Kandungan tertinggi metil palmitat sebanyak 47.57% dan kandungan terendah metil miristat sebanyak 1.502%. Hasil uji densitas sebesar 815 – 880, viskositas sebesar 2.3 – 6.0 cST, kadar air sebesr 210.667 – 366.750, uji warna ASTM *Copper Strip* dan korosi bilah tembaga berurutan sebesar no 3 dan kelas 1 A. Nilai opasitas terbesar tercapai pada putaran 3000 rpm. Emisi hidrokarbon (HC) menghasilkan rata-rata tidak menghasilkan HC. Emisi gas buang karbon monoksida (CO) menghasilkan rata-rata 0.05% volum. Emisi kadar CO_2 dalam gas buang memperlihatkan rata-rata 0.2% volum.

Kata kunci: Minyak Jelantah, FAME, Opasitas, Emisi

INTRODUCTION

Motorized vehicles are increasing every year as a means of transportation. It is the main cause of urban air pollution. The condition of motor vehicle emissions comes from fuel and combustion in the engine. Complete combustion produces the highest emissions, namely carbon dioxide (CO2) and water vapor (H2O). Fossil fuels emit almost all CO, HC, SO2, NO2 and particulate gases that are harmful to health. Telaoembanoea (2016) along with Rosdiyanti and Kaharmen (2020) state that all vehicles emitting and using the right fuel will result in better engine performance, better fuel economy, and lower emissions, however, emissions from diesel engines are very dangerous. Elfiano et al (2017) define that a diesel engine is a type of internal combustion engine whose ignition process does not use a spark ignition engine but utilizes heat from compressed air (compression ignition engine). Suyanto et al (2015) said that Diesel engines have higher compression than gasoline engines, which ranges from 12: 1 – 24: 1 and are capable of self-ignition at temperatures of 340°C – 350°C and compression up to 675°C, then injecting fuel in the combustion chamber.

An important input component that affects performance in addition to the condition of the Diesel engine is the quality of the fuel. Diesel engines currently use fuel, namely Diesel B20, Dexlite B20, and Pertamina DEX, all of which have different characteristics and properties, including the cetane number. Solar B20 is 80% diesel oil mixed with 20% fatty acid methyl ester (FAME) fuel with a cetane number of 48. Dexlite B20 is Pertamina's newest diesel engine fuel oil with a cetane number of 51 and a sulfur content as high as 1,200 ppm (parts per million). Pertamina Dex stands for Diesel Environment Extra and has a minimum cetane number of 53 with the lowest sulfur content of 300 ppm, so the performance is higher. (Rosdiyanti and Kaharmen, 2020).

Soerawidjaja (2002) suggests that the current research trend is the use of used cooking oil to turn biodiesel into a viable alternative fuel. Many Indonesian people do not know about the great potential for recycling used cooking oil or what is commonly called used cooking oil (waste vegetable oil or WVO, also known as waste cooking oil or WCO and use cooking oil or UCO). The National Team for the Acceleration of Poverty Reduction (TNP2K) and Traction Energi Asia (2020), stated that domestic consumption of palm cooking oil in 2019 reached 16.2 million kiloliters (KL), the average used cooking oil produced was in the range of 40-60 % or 6.46-9.72 million KL. Unfortunately, the used cooking oil collected in Indonesia has only reached 3 million KL, which is only 18. 5% of the total consumption of palm cooking oil in the country. Only around 570 KL is converted into biodiesel or other purposes from the 3 million KL collected. Meanwhile, for recycling and export of cooking oil, the remaining 2.4 million KL is used.

Several countries use cooking oil to produce energy. According to Fitriani et al (2016) and Yudha et al (2018) stated that there is no significant difference in the physicochemical composition of biodiesel and diesel fuel, thus indicating that used cooking oil can be processed into biodiesel. In addition, Pratiwi et al (2016) and Fitriani (2016) confirmed that used cooking oil can be used as biodiesel for degumming, esterification and transesterification processes. The value of the methyl ester (fatty acid methyl ester) compound was detected and the FAME composition was analyzed using the GCMS tool to determine the yield of biodiesel from used cooking oil. Therefore against this background, Researchers are very interested in conducting research using biodiesel from used cooking oil at Vyatra PEM Akamigas hostel because on average it produces 50 – 60 liters/month of waste or around 600 – 720 liters/year. Determination of opacity, performance and concentration of diesel engine exhaust gas when mixed with PT Pertamina's Solar TBBM, criteria for biodiesel free fatty acids (ALB) < 0.4 and humidity $< 0.05\%$. It is hoped that this research can recycle used cooking oil around Cepu and revive the people's economy.

METHOD

This research method uses experimental trials in the form of testing in the laboratory and field (laboratory and field research). Data processing methods use quantitative data analysis methods that help describe, show or summarize data in a constructive way, describe data in the form of data checking (editing), classification (classifying), verification (verifying), analysis (analysing), interpretation (interpretation).) and making conclusions (concluding). Determination of used cooking oil parameter tests in the form of physical tests, odor, color, peroxide number, free fatty acid content, acid value, water content using SNI 01-3741-2002 standard concerning Cooking Oil Quality Requirements. While the parameter test results for processing used cooking oil into biodiesel use the SNI 04-7182-2015 standard. Process testing starts from the purification process (despicing process, neutralization, bleaching), esterification process, transesterification process, washing process and analysis process using gas chromatography. As for the opacity test and exhaust emissions using a emission analyzer.

RESULT AND DISCUSSION

Result

The results of the Vyatra X dormitory cooking oil test with 4 sample test codes, namely UCO 1 = Fish Fryer, UCO 2 = Chicken Fryer, UCO 3 = Tofu Tempe Fryer and UCO 4 = Mixed Fryer as shown in Figure 2. Test results for used cooking oil (used cooking oil) from 4 test samples namely UCO 1 – UCO 4 with the test criteria of smell, taste, color, moisture content, free fatty acids, acid number and peroxide number as shown in Table 1 and using GCMS analysis to determine the content of methyl ester compounds as shown in Table 2 .

Table 1. Test Results for Used Cooking Oil

Test Criteria	Unit	Quality	UCO1 Average 3x	UCO2 Average 3x	UCO3 Average 3x	UCO4 Average 3x
Smell	-	Normal	Rancid	Rancid	Somewhat rancid	Very rancid
Flavor	-	Normal	Bitter Acid	Bitter Acid	Bitter Acid	Bitter Acid
Color	-	Pale Yellow White to Yellow	Dark Chocolate	Somewhat Thick	Yellow Brown	Very Dark Dark Chocolate
Water content	% b/b	0.01 – 0.30	0.43	0.32	0.28	0.59
Free fatty acids		Max 0.30	0.41	0.35	0.30	0.62
Acid Number	mgKOH/g	Max 0.60	1.46	1.47	1.10	1.59
Peroxide Number	mg O2/100 g	Max 1.00	4.01	3.89	2.38	4.67

Table 2. GCMS Analysis Results for Methyl Ester Compounds

Compound	Content (%)			
	UCO1	**UCO2**	**UCO3**	**UCO4**
Methyl Myristate	1.6	1.61	1.74	1.06
Methyl Palmitate	45.95	48.51	48.87	46.95
Glycerol Trilaurate	0.29	0.38	0.35	0.3
Glycerol Trilaurate	0.36	0.26	0.37	0.58
Methyl Oleate	42.75	43.38	43.16	42.36
Methyl Stearate	3.89	4.25	4.09	2.89
Methyl Linoleate	3.85	-	-	5.85
Total	**98.69**	**98.39**	**98.58**	**99.99**

Test results of 4 samples of used cooking oil (used cooking oil), namely UCO 1 – UCO 4 to determine the characteristics of biodiesel from esterification and esterification-transesterification tests with flash point test criteria, color, copper blade corrosion, viscosity, density, water content, acid number, cetane and yield.

Table 3. Results of Blending Solar Analysis with UCO 3 B 30% – B 50%

Testing	Sample						Unit	Condition	Test Method
	B 30		**B 40**		**B 50**				
Flash Point	78	77	81	83	88	89	°C	52	ASTM D93
Color	3	3	3	3	3	3	No. ASTM	3	ASTM D1500
Copper Blade Corrosion	1 A	1 A	1 A	1 A	1 A	1 A	% mass	Class 1	ASTM D130
Kinematic viscosity 40°C	3,423	3.42	3,568	3,563	3,698	3,695	mm/s (cSt)	2.3 – 6.0	ASTM D445-17a
density	841	841	844	844	845	845	kg/m3	815–880	ASTM D4052/D1298
Water content	277.4	278.6	242	239.1	305.3	306.1	% volumes	500	ASTM D6304
Sulfur	7.10	7.00	5.50	5.45	4.99	5.05	mg/kg	20	ASTM D2622
Strong Acid Number	0	0	0	0	0	0	mg-KOH/g	0.4	ASTM D974-14
Total Acid Number	0	0	0	0	0	0	mg-KOH/g	0.6	ASTM D664
Cetane Index	49.6	49.5	48.8	48.9	48.4	48.4	-	45	ASTM D4737-10
Cetane number	49	49	48	48	48	48	-	48	ASTM D613

The results of the analysis of the UCO 3 blending test with B0% - B50% diesel fuel through the test criteria for flash point, color, copper blade corrosion, viscosity, density, water content, acid number, and cetane number.

Table 4 Results of UCO 3 Blending Analysis with Solar B 30% – B 50%

Testing	**Sample**						**Unit**	**Condition**	**Test Method**
	B 30%		**B 40%**		**B 50%**				
Flash Point	42	42	47	48	55	56	°C	52	ASTM D93
Color	3	3	3	3	3	3	ASTM No	3	ASTM D1500
Copper Blade Corrosion	1 A	1 A	1 A	1 A	1 A	1 A	% mass	Class 1	ASTM D130
Kinematic viscosity 40°C	3.68	3.69	3.08	3.09	3.62	3.62	mm/s (cSt)	2.3 – 6.0	ASTM D445-17a
density	831	831	839	839	837	837	kg/m3	815–880	ASTM D4052/D1298
Water content	235	236	208	211	188	186	% volumes	500	ASTM D6304
Sulfur	2.24	2.35	2.83	2.85	2.24	2.30	mg/kg	20	ASTM D2622
Strong Acid Number	0	0	0	0	0	0	mg-KOH/g	0.4	ASTM D974-14
Total Acid Number	0	0	0	0	0	0	mg-KOH/g	0.6	ASTM D664
Cetane Index	50.8	51	51.3	51.5	52.1	51.9	-	45	ASTM D4737-10
Cetane number	50	50	51	51	51	51	-	48	ASTM D613

The results of the analysis of the blending opacity testing of Solar with UCO 3 B 0% - B 50% and UCO 3 with B0% - B50% diesel and using a Mitsubishi Colt Diesel FE104 100 PS 3,298 cc truck engine at the Jepon workshop, Blora and accompanied by the Head of the Transportation Service Blora, namely Mr. Sutiyono Figure 1.

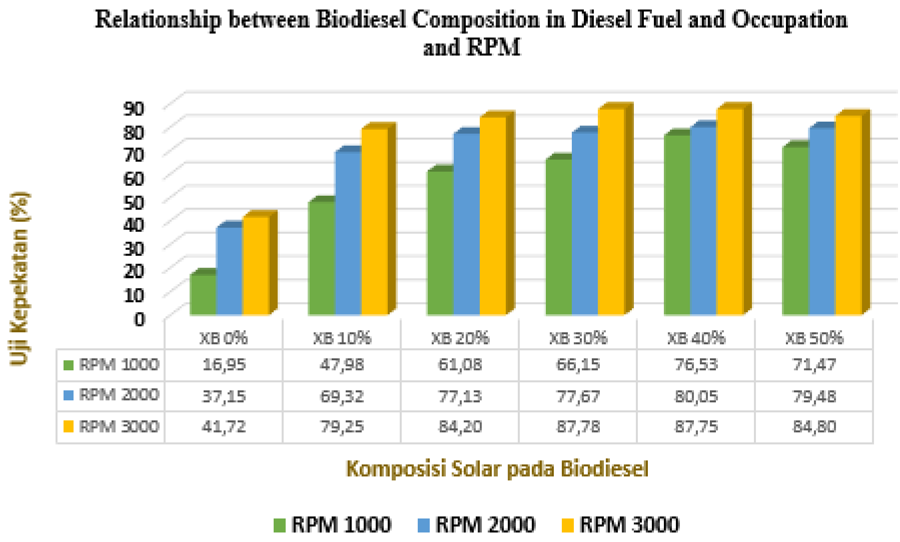

Figure 1 Relationship between the Composition of Biodiesel in Diesel Fuel with Opacity and RPM

The occupational test equipment uses the Auto Check Automobile Emission Analyzer belonging to the Semarang Envilab Laboratory through the opacity test criteria or concentration test based on engine speed (RPM) and blending diesel fuel with UCO 3.

Results of analysis of emission testing of blending Solar with UCO 3 B 0% - B 50% and UCO 3 with diesel B0% - B50% and using a Mitsubishi Colt Diesel FE104 100 PS 3,298 cc truck engine at the Jepon workshop, Blora and accompanied by the Head of the Transportation Service Blora, namely Mr. Sutiyono. The test results are compared with the Minister of Environment Regulation Number P20 concerning Emission Quality Standards for 2017 category M, category N and category O Euro-4 (diesel) CO emissions: 0.50 g/ km HC + NOx: 0.30 g/km NOx: 0.25 g/km PM: 0.025 g/km.

Discussion

The results of the used cooking oil test in Table 1 show that UCO 1 – UCO 4 has passed the SNI 01-3741-2002 Standard for Cooking Oil Quality. Based on Table 4.1, it shows that the sample of used cooking oil does not meet the eligibility requirements for use or reuse because the percentage value of free fatty acids, acid number and peroxide value respectively does not meet the cooking oil quality standard, namely exceeding 0.3; 0.6; and 1.0 besides that it is also toxic. The results of testing the color of used cooking oil as shown in Table 1 show that the color of UCO 4 is very dark brown compared to UCO 1 – UCO 3. Ketaren (1986), Nuri et al (2000), Siti et al (2001), Suroso (2013) state that embezzlement of used cooking oil caused by oxidation damage. Nawar (1985) and Ketaren (1986) stated that the cause of the brown color of used cooking oil is the presence of bonds between carbohydrate and protein molecules called the Maillard reaction, which is the reaction between the carbonyl group and the amine group in protein. Repeated overheating causes polymerization and Maillard reactions which thicken and darken the oil (Nawar, 1985; Ketaren, 1986; Siti et al, 2001; Suroso, 2013). The longer you use cooking oil, the darker the color. The higher the heating, the more peroxide compounds are formed and the color of the oil gets darker (Nuri et al, 1997; and Suroso, 2013). Nawar (1985), Ketaren (1986) and Suroso (2013) suggest that this can occur during the handling, storage and use of oil. However,

The results of the water content test in Table 1 show that the black and brown used cooking oil is higher than the SNI quality standard with the highest UCO 4 being 0.59 and the lowest UCO 3 being 0.28 which means the oil is damaged and can no longer be used due to health problems. Suroso (2013) suggests that the high water content of oil is caused by moisture when frying, the frying process, or storage is exposed to and filled with cooking oil so that the water content in the oil increases (Siti et al, 2001). High quality oils have little free fatty acids or low acid numbers. The test results in Table 1 show that the free fatty acid content of black used cooking oil is higher than that of brown used cooking oil, namely 0.62% and 0.30%. This means that the oil has a high acid number. Black used cooking oil has a higher acid value than brown used cooking oil. Sari and Kembaren (2019) state that high amounts of free fat cause obstruction. That is, the formation of soap inhibits methanol from reacting with triglycerides. This high acid number means that it corresponds to a high free fatty acid content. Many triglycerides break down into free fatty acids through hydrolysis reactions, and the presence of water produces glycerol and free fatty acids (Siti et al, 2006; Widayat et al, 2020; Mas`ud et al., 2008; Pakpahan et al., 2013). The taste on the surface of the tongue and the smell that increases cholesterol levels in rancid oil if the fat with free fatty acids is greater than 1% (Suroso, 2013). Sari and Kembaren (2019) state that high amounts of free fat cause obstruction. That is, the formation of soap inhibits methanol from reacting with triglycerides. This high acid number means that it corresponds to a high free fatty acid content. Many triglycerides break down into free fatty acids through hydrolysis reactions, and the presence of water produces glycerol and free fatty acids (Siti et al, 2006; Widayat et al, 2020; Mas`ud et al., 2008; Pakpahan et al., 2013). The taste on the surface of the tongue and the smell that increases cholesterol levels in rancid oil if the fat with free fatty acids is greater than 1% (Suroso, 2013). Sari and Kembaren (2019) state that high amounts of free fat cause obstruction. That is, the formation of soap inhibits methanol from reacting with triglycerides. This high acid number means that it corresponds to a high free fatty acid content. Many triglycerides break down into free fatty acids through hydrolysis reactions, and the presence of water produces glycerol and free fatty acids (Siti et al, 2006; Widayat et al, 2020; Mas`ud et al., 2008; Pakpahan et al., 2013). The taste on the surface of the tongue and the smell that increases cholesterol levels in rancid oil if the fat with free fatty acids is greater than 1% (Suroso, 2013). This high acid number means that it corresponds to a high free fatty acid content. Many triglycerides break down into free fatty acids through hydrolysis reactions, and the presence of water produces glycerol and free fatty acids (Siti et al, 2006; Widayat et al, 2020; Mas`ud et al., 2008; Pakpahan et al., 2013). The taste on the surface of the tongue and the smell that increases cholesterol levels in rancid oil if the fat with free fatty acids is greater than 1% (Suroso, 2013). This high acid number means that it corresponds to a high free fatty acid content. Many triglycerides break down into free fatty acids through hydrolysis reactions, and the presence of water produces glycerol and free fatty acids (Siti et al, 2006; Widayat et al, 2020; Mas`ud et al., 2008; Pakpahan et al., 2013). The taste on the surface of the tongue and the smell that increases cholesterol levels in rancid oil if the fat with free fatty acids is greater than 1% (Suroso, 2013).

Sari and Kembaren (2019) reported that peroxide is the first product that determines the level of breakdown of vegetable oil through oxidation and hydrolysis (enzymatic or non-enzymatic) during the heating process, and ketones and aldehydes oxidize the smell and taste of oil (Suroso, 2013; Sari and Kembaren , 2019) The test results in Table 1 show that the highest UCO 4 peroxide value is 4.67 and the lowest UCO 3 value is 2.38. In addition, it is linear, meaning that UCO 4 smells very bad and UCO 3 smells slightly rancid. Aziz (2008) suggested that 85% of the total biodiesel yield of the mixture comes from the transesterification of used cooking oil. In general, the factors that affect the transesterification reaction are agitation, temperature, catalyst, reactant ratio, and reaction time (Trambouze et al, 1988, Aziz, 2008).

The highest esterification yield value was UCO 3 of about 80% and the lowest UCO 4 was 40%, while the highest yield value for transesterification was UCO 3 of 81.33% and the lowest UCO 4 was around 61.7%. Analysis of the FAME content using the GCMS tool as shown in Table 2 shows that the methyl ester compound is 98.18% while the remaining glycerol is 0.72% and meets the quality requirements of SNI 7182-2015 at least 96.5%. The average dominance of FAME compounds in this study was 47.57% methyl palmitate and the lowest average content was 1.502% methyl myristate. The results of this study are in line with Ketaren (1986) and Yudha et al (2018) that the results of the dominance of the compound, namely Methyl Palmitate, are around 40-46% and 49.08%. The results of this study have differences in the results of the research of Setiawan et al (2017) with Sari and Kembaren (2019), where the dominance of the compounds was Methyl Oleate of 45.44% and 42.47%, Methyl Palmitate of 31.31% and 39.19%, Methyl Linoleate of 14.3% and 10.25%, and Methyl Stearate of 7.2%, while Sari and Kembaren (2019) did not contain Methyl Stearate. This difference may occur due to the different fatty acid composition of the used cooking oil, which can cause the resulting FAME to be different.

Formo (1997) and Ahmad et al (2016) stated that the effect of density or specific gravity of oil and methyl ester (biodiesel) depends on the length of the fatty acid chain, degree of unsaturation and ambient temperature because the longer the fatty acid chain, the higher the density. According to Ula and Kurniadi (2017); Sari and Kembaren (2019) explain density is the ratio between mass and a certain volume (oil density to water density) at a certain temperature. Density is related to heat output and power output from diesel engines, lower density produces higher heat and vice versa (Aziz, 2008). During the esterification and transesterification processes, the conversion of triglycerides is converted into methyl esters and the glycerol chains present in used vegetable oils are damaged, thereby reducing their density (Aziz, 2008; Aziz et al, 2011; Ahmad et al, 2016). This is proven in this study, the comparison of the calculation results of the esterification density in Table 3 and the transesterification results in Table 4 shows a significant decrease in density values. The average density test results in this study were 835 – 843, this means that they met the SNI quality requirements between the value range 815 – 880. Biodiesel must be stable at low temperatures, the lower the temperature, the higher the specific gravity of biodiesel and vice versa because glycerol has a fairly high density. thereby affecting the density of biodiesel (Ahmad et al, 2016). Do not use biodiesel in diesel engines, if the density of biodiesel exceeds the quality requirements, an imperfect reaction will occur during the conversion of vegetable oil. because it increases engine wear and emissions and causes engine damage (Sari and Kembaren, 2019). Ahmad et al, 2016). 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Viscosity plays a very important role in this case of fuel injection because biodiesel flows easily. The higher the viscosity, the thicker the oil and the less it flows, and vice versa (Ahmad et al, 2016; Ula and Kurniadi, 2017). The results of the test analysis of the average viscosity value in this study amounted to 3,133 – 3,698 cST, this means that it has met the SNI quality requirements between the value range of 2.3 – 6.0 cST. Low viscosity can cause leaks in the fuel injection pump, and viscosity that is too high can affect the work of the fuel injectors and make it difficult for the fuel to be expelled (Hardjono, 2000; Aziz, 2008; Aziz et al, 2011). The low viscosity of the fuel results in a spray that is too fine to penetrate the combustion cylinder,

The hygroscopic nature of biodiesel affects the storage process and mixing process with diesel fuel. The high water content of biodiesel makes it easy for microorganisms to grow and contaminate biodiesel, causing engine corrosion. In addition, the presence of water content in biodiesel over a long period of time increases the FFA value (acid value). The results of the analysis of testing the average value of water content in this study amounted to between 210,667 – 366,750 and this is smaller in terms of SNI quality, namely 500.

Copper plate corrosion is a measure of the corrosion rate of fuel against copper or brass components in the fuel system (Wahyuni et al, 2011). The higher the chromaticity value, the darker the color of the fuel, and if the color of the fuel exceeds a predetermined standard value, this indicates that there has been thermal degradation or a dark colored substance in the fuel (Hardjono, 2000., Wahyuni et al., 2011). The results of the ASTM Copper Strip color test and the corrosion of copper blades in this study indicate that color is entered at no. 3 and corrosion is entered at class 1 A, so this test meets the SNI quality requirements for color testing, namely no. 3 and the corrosion is in class 1 A.

Opacity describes the darkness or transparency of exhaust gas because the higher the opacity, the higher the part that is not visible due to exhaust fumes. The results of testing the blending opacity of Biodiesel in Diesel fuel in Figure 1 – Figure 4 show that the higher the engine RPM, the greater the soot yield and the largest opacity value is achieved at 3000 rpm. The higher the specified load opening, the greater the fuel requirement, the greater the air supply for combustion, and the incoming air is not only O2 gas, but mixed with exhaust gas. As a result, O2 gas does not burn completely and forms soot. The results of this study are not in accordance with the results of the research by Setyadji and Susiantini (2007) which states that the type of fuel tends to decrease as the engine speed increases. However, the results of this study are in line with the research of Syaiful and Budiman (2011) who found that the use of Isuzu Panther vehicle engines with indirect and diesel injection produces gas contaminated with O2 and incomplete combustion. Daryono and Mustiadi (2022) stated that biodiesel is a sulfur-free bioenergy and contains 10-12% O2, so it can reduce pollution and exhaust gas concentrations, meaning that the more biodiesel added the better it will be because the smaller the concentration test value, the more good means that the result of exhaust gas concentration is getting smaller but has an optimum limit.

The emission of hydrocarbons (HC) in exhaust gas that blends diesel fuel with UCO 3 B 0% - B 50% and UCO 3 with diesel B0% - B50% up to 99%. This also confirms that the combustion process that occurs with fuel containing biodiesel is more complete.

HC emissions are caused by the presence of hydrogen and carbon molecules in unburned fuel. HC emissions are low when there is plenty of air, but very high when there is not enough air. In addition, HC emissions can occur at low temperatures because the combustion process cannot take place. This proves that biodiesel is an environmentally friendly fuel, so that the use of biodiesel as a fuel can minimize environmental impacts.

The results of exhaust emissions of carbon monoxide (CO) as shown in Table 4.10 show an average yield of 0.05% by volume. This is because carbon monoxide (CO) is formed from a lack of oxygen so that the fuel cannot burn completely during the combustion process. Setyadji and Susiatini (2007) suggested that CO levels were formed due to increased rotation and high temperatures. The complete combustion reaction produces high levels of CO2 and H2O. This is because the more energy produced, the higher the CO2 level and vice versa. Table 11 shows the results of examining the CO2 content in the average exhaust gas of 0.2% by volume, and it can be said that there is no significant difference in the CO2 content in the biodiesel blended fuel.

CONCLUSION

Test results for used cooking oil with UCO 1 – UCO 4 samples with the test criteria for smell, taste, visual color, water content, free fatty acid, acid number and peroxide value do not meet the quality standards of SNI 01-3741-2002 Requirements for Cooking Oil Quality do not meet the requirements feasibility for use or re-consumption because it is toxic. The highest esterification yield value was UCO 3 of about 80% and the lowest UCO 4 was 40%, while the highest yield value for transesterification was UCO 3 of 81.33% and the lowest UCO 4 was around 61.7%. The average dominance of FAME compounds in this study was 47.57% methyl palmitate and the lowest average content was 1.502% methyl myristate;

The results of analysis and calculation of density, viscosity, water content tests sequentially 835 – 843, 3,133 – 3,698 cST, 210,667 – 366,750 have fulfilled the quality requirements of SNI 7182-2015. The results of the ASTM Copper Strip color test and the corrosion of copper blades in this study indicate that color is entered at no. 3 and corrosion is entered at class 1 A, so this test meets the SNI quality requirements for color testing, namely no. 3 and the corrosion is in class 1 A. The results of testing the blending of Biodiesel fuel in Solar and vice versa show that the greatest opacity value is achieved at

3000 rpm rotation, does not produce hydrocarbon (HC) emissions, carbon monoxide (CO) emissions of 0.05% by volume and CO2 emissions of 0.2% by volume.

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