

Characteristics and Assessment of Fuel Properties from Used Cooked Oil as Diesel in Ken Saro Giwa Polytechnics Restaurants Rivers State

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Abstract

Original Research Article

The fuel characteristics of waste vegetable cooking oil has been sourced locally from Ken Saro Giwa Polytechnics restaurants Bori Rivers State. The materials used involved thermometer, 50 ml flask, dropper blender, weighing scale, methanol 99% purity, funnel, phenolphthalein indicator, graduated pipette, potassium hydroxide of 85 % purity, sodium hydroxide, one litre high density polythene container, two-twenty litres capacity settling and separation containers and wasted vegetable oil (yellow grease). It was processed, acceded and tested for its fuel characteristics. The methods adopted were purification and heating to 100°C for about 45 minutes, titration to obtain free fatty acids, transesterification and preparation of potassium-methanoxide in 200 ml of methanol, separation that involved settling of glycerol in container for 24-hours. After that, it was washed and dried to obtain the oil (biodiesel), which was heated to about 110°C for about thirty minutes to evaporate off residual water from the washing process. The fuel characteristics of viscosity, cloud point, sulphur, copper corrosion, distillation, and densities were determined by Nigerian Petroleum Oil Refinery Eleme Rivers State. The effects of temperature on viscosity and density of the fuel were conducted at the department of chemistry while the calorific value was determined at the Department of Mechanical Engineering. Result of the cetane index number showed that all the methyl esters was higher than that of diesel. The viscosity dropped when the oil was heated in the Engine with increased in temperature from 7.72cST at 25°C and varied from 4.546 cST for soy methyl ester to 5.62 cST for Low FFA yellow grease. The biodiesel had a cloud point of 14°C, meaning that the fuel should not be used in areas where the local temperatures falls below 14°C. The sulphur contents for the blends were 0.14, 0.18, 0.22, 0.39 and 0.545% for BD70, BD50, BD30, BD10 and Diesel respectively which suggested that use of biodiesel as an additive result was a decrease of sulphur content. The copper strip corrosion proved that the strip was somewhat stained and same as a newly polished strip, while heat of combustion of diesel and biodiesel were 53.37 MJ/kg and 47.31 MJ/kg, which was 12.5 % difference by combustion

Keywords: *Properties, used-edible-oil, characteristics, assessment, fuel and restaurants.*

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INTRODUCTION

From the time when the earliest oil disaster in 1980s, numerous substitute fuels have been examined as possible additions to predictable petroleum established materials. The concerned then was fuel supply and security. Now, responsiveness has moved to the use of renewable energies in edict to reduce environmental effects of combustion of fossil fuels [1]. One category of fuel that is in good health suitable for diesel engines is that built on vegetable oils. Odhiambo and Munavu, [2] noted in their investigations with vegetable oil based fuels in diesel engines designate that their recital is associated to that of diesel fuel. Besides, they are right now valued amongst the energy fuels measured as the most auspicious standby for the very

evaluated and diminishing fossil fuels. The two organic fossil fuels compounds of Ethanol and Methanol are the important produce from biomass sources. Conversely, none of these fuels is suitable to be used in diesel engines because they necessitate the application of great compression ratios, ignition agitators and backing devices. According to Scholl and Sorenson, [1], single means of exhausting alcohol is to combine it with vegetable oils via transesterification method to form the equivalent ester of vegetable oil (biodiesel). Hence because of this, used oil is usually drained as waste oil and changed with fresh oil after specific time duration of cooking usage. Used vegetable oils and fats derived from cooking activities in hotels, restaurants, schools etc, pose a major disposal problem in many parts of the world, more so in the context of stringent

environmental audits and Rivers State of Nigeria. This poses environmental pollution and needs to be recycled. In the past, much of these waste products have been used in the production of animal feeds. Disposal in this manner has since diminished. It is currently acknowledged that one of the most attractive disposal method is use it as alternate bio-fuel in diesel engines. Nigerian's domestic production of edible oils is estimated at 760,000 tonnes, which is about one-fourth of its annual demand, the remainder is imported [3]. Considering the high quantities of vegetable oils consumed in the country, used vegetable oil produced country wide does present an opportunity for economic conversion to biodiesel. Vegetable oils are an attractive source of biodiesel but present some technological challenges due to the high percentage of free fatty acids (1-13%). The used vegetable oils are known as yellowish grease while biodiesel which is processed from this oil is known as yellowish greased methyl ester.

MATERIALS AND METHODS

Method for processing oil

The wasted vegetable oils were locally sourced from Mama Onyinye restaurant Pollo Park Enugu, Enugu State and King Saro Giwa Polytechnics restaurants Bori, Rivers State
The methods adopted were as stated;

Materials

The materials used include: Thermometer, 50 ml flask, Dropper Mixer / blender, weighing scale (accurate to 0.01 grams), Methanol 99% purity, Funnel, Phenolphthalein indicator, graduated pipette, Potassium Hydroxide (KOH) 85 % purity, Sodium Hydroxide (NaOH), one litre high density polythene container, two 20 litre capacity settling and separation containers with tap at the bottom and wasted vegetable oil (yellow grease)

Method

The methods involved includes

Purification method, which involved the collection of wasted cooking oil were heated to about 100°C for about 45 minutes, it was stirred to reduce water content in the oil and then passed through a sieve still hot to filter off solid particles and debris. After that purifications were made

Determination of the amount of KOH required for titration of free fatty acids. These were done by using; 1 gram of NaOH dissolved in one litre of distilled water in the high density container to make a 0.1 % lye solution, by applying 1 ml of dewatered waste vegetable oil mixed with 10 ml of isopropyl alcohol in a 50 ml flask, followed by the mixture of warmed by hot water while stirring until the oil completely dissolved in alcohol. Again, two drops of phenolphthalein indicator were added to the oil using a dropper the lye solution was added drop wise resulting to mixture while stirring

action until the solution turned and stayed pink for about 25 seconds.

Afterwards, number of millilitres of lye solution used for titration plus 3.5 (amount required for fresh oil) now two numbers of grams of NaOH were then required per litre of oil. Later KOH was added for transesterification, the basic lye quantity was adjusted to corresponding strength of KOH.

Titration method, which involved the analysis for the running of test were as;

2.5 ml of 0.1% NaOH solution to be used to titrate the Free fatty acids (FAAs).

4.5 grams of NaOH amount was required for one litre of fresh oil

Titration result 2.5 ml

Therefore, $4.5 + 2.5 = 7 \text{ grams}$ of NaOH for every litre of used waste oil

Amount of 85 % KOH that will give the equivalent strength of 7 g of NaOH

$7 \times 2.65 = 11.25$ grams of KOH per litre of used waste vegetable oil.

(1.65 - convert quantity for 85% KOH)

Transesterification Method

Which involved Potassium-methanoxide was preparation by dissolving the predetermined amount of KOH, (11.25 grams) in 200 ml of methanol (in a high density polythene container) for every litre of cleaned used waste vegetable oil to be processed. Then the oil was heated to 65°C then mixed with potassium-methanoxide at a ratio of 5:1 respectively. The mixture was vigorously stirred in a 10 litre capacity blender for about 55 minutes and then transferred to a settling container to allow glycerol to separate from biodiesel.

Separation Method

Which involved settling of glycerol that is higher density than biodiesel, it settled at the bottom of the container. After 24-hours of separation, the tap beneath the container was opened and glycerol was drained off.

Step four: Washing and drying.

Crude biodiesel was washed three times by agitation with clean water to remove traces of methanol and KOH from the oil. After each wash, the oil was transferred to the settling container for about four hours where it was allowed to separate. The amount of water used in each wash was equal to the amount of oil being cleaned. Water was then drained off after separation. It was noted that using warm water hastened the separation processes.

Finally, the oil (biodiesel) was heated to about 110°C for about thirty minutes while stirring to evaporate off residual water from the washing process. The flow chart of the waste oil purification and biodiesel generation is shown in figure 2.1.

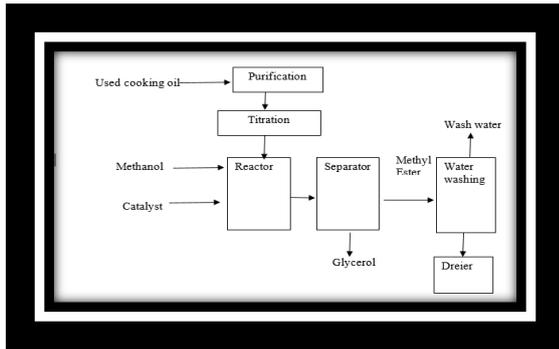


Fig-2.1: Process flow chart for biodiesel production from used edible oils.

Fuel characterization

When the fuel characteristics of viscosity, cloud point, sulphur, copper corrosion and distillation reached 15°C and 20°C, their densities were determined by Nigerian Petroleum Oil Refinery Eleme Rivers State. Experiments on the effects of temperature on viscosity

$$\rho_o = \frac{m_1 - m_0}{U_0} \quad (2.1)$$

Where ρ_o = density of the oil, U_0 = volume of the bottle, m_0 = mass of empty bottle and m_1 = mass of empty bottle + mass of fuel sample

Viscosity

The U-Tube viscometer figure 2.2, was used to determine the viscosity of the oil samples while plate 2.1 shows the mounting. Tests conducted with the U-Tube viscometer were immersed in a water bath that was upheld at a constant temperature using an electric water heater and regulated with a contact thermometer.

and density of the fuel were conducted at the Department of Chemistry while the calorific value was determined at the Department of Mechanical Engineering. The materials, parameters and processes to be used are described as.

Density

The density bottles were determined with the density of the oil. An unfilled bottle of identified volume and mass was full with a fuel sample. The bottle and the fuel sample were then raised up to the chosen temperature using a heated water bath whose temperature was held at the chosen side by side by use of an electric water heater. The bottle was then balanced and the mass was distinguished. This technique was repetitive a number of times and the mean value for mass was secondhand to calculate the density. The density was calculated using equation (2.1) as;

The fuel sample was introduced into the viscometer up to the point marked A. It was then sucked to point B and allowed to flow down. The time taken for the level to reach point C was recorded. The test was done several times and the average time recorded. The procedure was repeated with water.

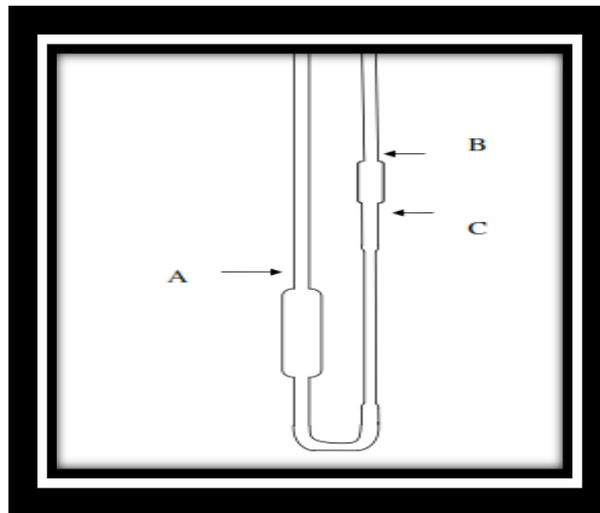


Fig-2.2: U-Tube viscometer

Viscosity was computed using equation (2.2) as;

$$u_o = \frac{t_o U_w}{t_w} \quad (2.2)$$

Where U_0 is kinematic viscosity of the oil, U_w is kinematic viscosity of water, t_o is time taken for oil to flow from point B to C and t_w is time taken for water to flow from point B to C



Plate-2.1: Mounted U-tube viscometer

Calorific value

Plate 2.2 is a set-up for bomb calorimeter used for calorific value determination. Benzoic acid was used to standardize the calorimeter. One gram of sample was put in a crucible and weighed. It was then placed in the bomb, which was pressurized to 23 atm with oxygen. The bomb was placed in a vessel containing a measured quantity of water (1750 ml). The ignition circuit was

connected, the stirrer switched on and the water temperature recorded. After the temperature had stabilized, the bomb was fired and the temperature rise was recorded every minute until a constant temperature was noted. The pressure was released and the bomb was inspected to ensure that the sample was completely burnt. The calorific value was computed using equation (2.3) and according to sample calculation in Table 2.1

Table-2.1: Temperature recorded in °C after every one minute

36.47	39.61	40.39
36.42	40.19	40.34
36.40	40.37	40.32
36.40 *	40.44 *	40.29
38.05	40.44	40.22

$$\text{Cooling correction} = nv + \left(\frac{v_1 - v}{t_1 - t}\right) \left(\sum_1^{n-1}(t) + \frac{1}{2}(t_0 + t_n) - nt\right) \quad (2.3)$$

Where: n = time in minutes between firing and the first reading after the temperature begins to fall from the maximum, v is the rate of fall of temperature per minute during the pre-firing period, v_1 is the rate of fall of temperature after the maximum temperature, t and t_1 are the average temperature during pre-firing and firing periods. $\sum_1^{(n-1)}(t)$ is sum of readings between during the period between firing and the start of cooling, t_0 is temperature at the moment of firing and t_n is first temperature after the rate of change of temperature becomes constant. Source: Eastop and Mc Conkey [5].

$$\text{Thus, when } n = 6; v = \frac{36.47 - 36.40}{3} = -0.0233; v_1 = \frac{40.44 - 22}{6} = 0.0367; t = 36.42; \text{ and } t_1 = 40.33$$

$$\frac{1}{2}(t_0 + t_n) = \frac{1}{2}(36.40 + 40.44) = 28.42 \quad \sum_1^{n-1}(t) = 148.65$$

$$\text{Cooling correction} = -6 \times 0.0233 + [(0.0367 + 0.0233) / (30.33 - 26.42)] \times (148 + 28.42 - 158.52) = 0.14$$

$$\text{Temperature change} = t_n - t_0 + \text{cooling correction}$$

$$= 40.44 - 36.40 + 0.14 = 4.18$$

$$\text{Calorific value} = \frac{\text{Total water equivalent} \times \text{specific heat capacity} \times \text{temperature rise}}{\text{Weight of sample}} \quad (2.4)$$

$$= \frac{2270 \times 4200 \times 4.18}{1} = 39.85 \text{ MJ / kg}$$



Plate-2.2: Bomb calorimeter used for the calorific value

$$\text{Temperature rise} = t_o - t_n + \text{cooling correction} \quad (2.5)$$

$$\text{Cooling correction} = nv + ((v_1 - v)/(t_1 - t)) \{ \sum_1^{n-1} (t) + 0.5(t_0 + t_n) - nt \} \quad (2.6)$$

Cetane index

The Cetane index was calculated using the equation provided by ASTM D 976

RESULTS AND DISCUSSION

Fuel properties

Table 3.1 shows the fuel classification data of biodiesel, diesel and biodiesel-diesel blends. From

diesel and biodiesel criteria, the results were compared to check used the appropriateness of the fuel. The outcome was of the results were linked to those described by Kinast [4], that discussed the properties of seven esters for soy, canola, lard, edible tallow, inedible tallow, low FFA Yellow grease and High FFA yellow grease. These results were analysis under subsequent sections in line with Kinast [4].

Table-3.1: Biodiesel, diesel and biodiesel-diesel blends fuel classification data

Sample identity Property	Biodiesel	Biodiesel 70	Biodiesel 50	Biodiesel 30	Biodiesel 10	DIESEL
Density @ 20°C (Kg/m ³)	882.1	874.4	867.8	861.2	834.9	847.9
Density @ 15°C (kg/m ³)	886.6	878.3	871.2	865.4	858.3	851.3
Cetane index	42.45	44.37	46.68	46.88	46.74	52.44
Viscosity (eST) 25°C	7.72	5.56	4.75	4.32		3.86
Cloud point	14	11	6	8	9	9
Sulphur	0.04	0.14	0.18	0.22	0.4	0.555
Copper corrosion	1B	1B	1B	1B	1B	1B
Calorific value	38.52	39.72	40.38	41.38	42.68	43.38

Cetane index.

Since the least standard centane index is 40 by ASTM D 975 standard, Table 3.1 showed that produced biodiesel and its blends is acceptable because the values of centane were all above 40. The cetane index of biodiesel and diesel were 42.45 and 52.44. There was a small difference between blends of biodiesel 10, 30 and 50 respectively from Table 3.1. Kinast [4] noted that apart from Soy Methyl Ester whose cetane number was

50.2, all the methyl esters had cetane numbers that was higher than that of diesel Table 3.3

Viscosity

The biodiesel viscosity at 25°C was 7.72cST, which is double the one of diesel that had 3.86cST. The viscosity dropped when the oil was heated in the Engine with increased in temperature from 7.72cST at 25°C. The effects of heating oil on viscosity are shown in

Figure 3.2. As for blends, the viscosity increased linearly with increase in biodiesel content in the mixture in Figure 3.3. The standard ASTM D 975 recommends 1.9 cST and 6.5 cST at 50 viscosity of biodiesel. The viscosity of biodiesel @50°C to 7.72ct at 90°C as

Table -3.2: Biodiesel, diesel and biodiesel-diesel blends for optimum operating limits

Sample identity Temperature 25°C	Biodiesel 90	Biodiesel 70	Biodiesel 50	Biodiesel 30	Biodiesel 10	DIESEL 5
Viscosity (eST)	7.72	5.56	4.75	4.32	4	3.86

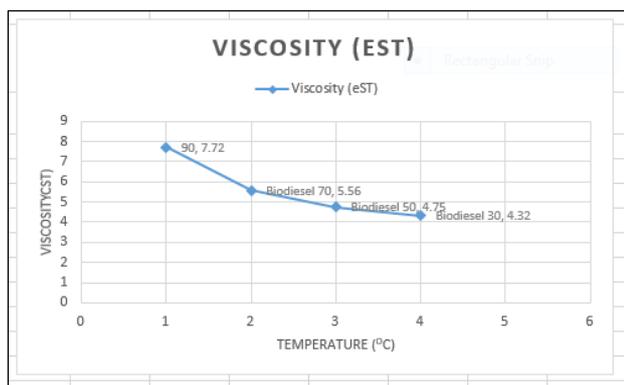


Fig-3.2: Effects of temperature on viscosity of biodiesel

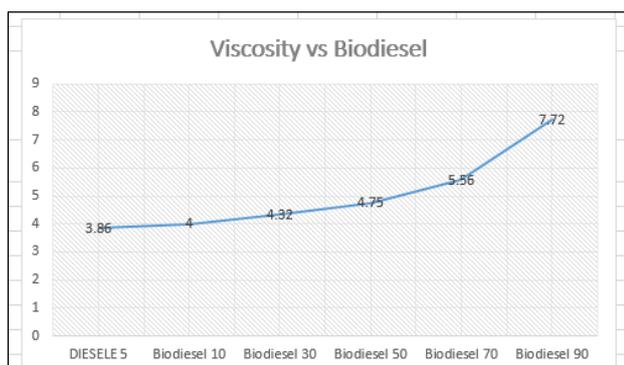


Fig-3.3: Viscosity variation with increase in biodiesel concentration in the blends

Cloud point

The ASTM D 975 does not agree the limits for cloud point but noted that it varies with local climatic conditions. According to Table 3.1, biodiesel had a cloud point of 14°C, this means that the fuel should not be used in areas where the local temperatures fall below 14°C. Blending biodiesel with diesel condensed the cloud point such that BD10, BD30, BD70, BD90 and diesel recorded a cloud point of 9, 8, 6, 11 and 9°C respectively. Results reported by Kinast [4] on the seven methyl esters showed that the cloud point varied from as low as -3°C to as high as 42°C

Sulphur content

In figure 3.4 the Sulphur content of the fuel samples studied exhibited an increase with decrease in biodiesel concentration in the blend. Biodiesel had the lowest sulphur content of 0.04% which is within the

optimum operating limits for viscosity of biodiesel. The viscosity of 50°C was 4.75 cST, which is well within the recommended range Table 3.2. From the study by Kinast [4], the viscosities varied from 4.546 cST for soy methyl ester to 5.62 cST for Low FFA yellow grease.

standard specification of 0.5 %. The sulphur content for the blends was 0.14, 0.18, 0.22, 0.39 and 0.545% for BD70, BD50, BD30, BD10 and Diesel respectively.

This indicates that the use of biodiesel as an additive result is a decrease of sulphur content. The maximum Sulphur content permitted by the standard D 975 for diesel is 0.5 %, diesel fuel surpassed this value by 0.045%. In Kinast's study, all the seven Methyl esters were found to contain sulphur levels that were less than 0.05% mass.

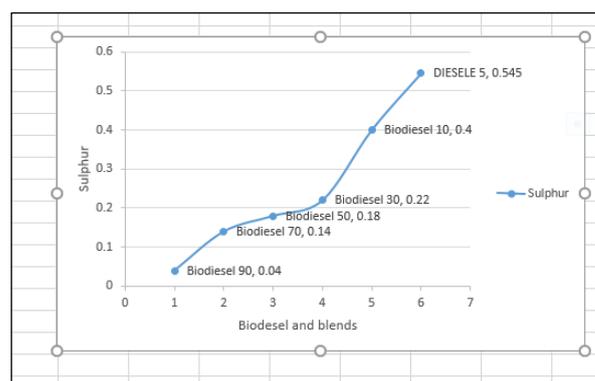


Fig-3.4: Variation of Sulphur content with increase in biodiesel concentration in the blend

Copper strip corrosion

The analysis gotten designed for copper strip corrosion of biodiesel, diesel and their mixtures designate that they have a least corrosion level of 1B on the distinct balance on Table 3.2. The 1B proves that the strip was somewhat stained and viewed virtually the same as a newly polished strip at the end of the test.

The ASTM D 975 tolerates a determined value of 3B. Consequently, biodiesel and its blends follow to this standard as reported by the results of Kinast [4], where a value of 1B was gotten for all the methyl esters estimated

Heat of combustion

The heat of combustion of diesel was determined to be 53.37 MJ/kg while that of biodiesel was found to be 47.31 MJ/kg, which is a difference of 12.5 %. The density of biodiesel was higher than that of diesel fuel (960 kg/m³ and 941 kg/m³ respectively at

25°C). Since injection pumps operate volumetrically, the energy content on volume basis is 36.52MJ/L for diesel and 43.85 MJ/L for biodiesel. This results in a theoretical increase in BSFC of 8.4 %. The mean values for heat of combustion of the methyl esters evaluated by Kinast [4], was 8.8% lower than that of diesel on mass basis.

Distillation

The standard ASTM D 975 indicates that No 2 Diesel fuel ought to have a lower limit of 381°C and

upper parameters of 437°C for 80% distillation point. However, results obtainable in Table 3.2 suggest that B 100, BD10 and BD30 had 80% distillation at 425°C, 420°C and 429°C. These values were within the variety indicated by ASTM D 975 standard. BD50, BD70 and Diesel exceeded this limits by 20°C, 26°C and 8°C respectively, as noted by Kinast [4] that all the seven-methyl esters investigated in his study had 80% distillation temperatures that showed beyond the maximum boundaries.

Table-3.2: Test results for Distillation of biodiesel, diesel and biodiesel-diesel blends

Observation point	Temperature °C					
	Biodiesel	BD10	BD30	BD50	BD70	Diesel
IBP	291	210	281	289	209	269
5%	301	383	355	337	309	317
10%	359	396	384	350	339	325
30%	418	409	403	379	361	348
40%	422	421	416	303	389	379
50%	423	421	422	310	397	389
60%		427	427	419	410	400
70%		429	431	424	419	409
80%		424	438	427	419	409
90%		443	441			435
95%		444				
FBF	326	441	448	428	420	434
	@50%	@85%	@80%	@74%	@70%	@85%

CONCLUSION

The fuel characteristics of viscosity, cloud point, sulphur, copper corrosion, distillation, and densities were determined by Nigerian Petroleum Oil Refinery Eleme Rivers State. The effects of temperature on viscosity and density of the fuel were conducted at the department of chemistry while the calorific value was determined at the Department of Mechanical Engineering. Result of the cetane index number showed that all the methyl esters was higher than that of diesel. The viscosity dropped when the oil was heated in the Engine with increased in temperature from 7.72cST at 25°C and varied from 4.546 cST for soy methyl ester to 5.62 cST for Low FFA yellow grease. The biodiesel had a cloud point of 14°C, meaning that the fuel should not be used in areas where the local temperatures falls below 14°C. The sulphur contents for the blends were 0.14, 0.18, 0.22, 0.39 and 0.545% for BD70, BD50, BD30, BD10 and Diesel respectively which suggested that use of biodiesel as an additive result was a decrease of sulphur content. The copper strip corrosion proved that the strip was somewhat stained and same as a newly polished strip, while heat of combustion of diesel and biodiesel were 53.37 MJ/kg and 47.31 MJ/kg, which was 12.5 % difference by combustion. These showed that the biodiesel characteristics from wasted

edible oil were better of that ordinary diesel, especially the sulphur content, viscosity and heat of combustion.

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