Increasing of quality biodiesel of Jatropha seed oil with biodiesel mixture of waste cooking oil

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Biodiesel is an alternative fuel which may replace fossil with one of its potential sources being *Jatropha curcas*, a non-edible plant. However, the quality of *Jatropha* seed oil needs to be improved by decreasing the viscosity and increasing the calorific value. Furthermore, the biodiesel mixture of *Jatropha* seed and waste cooking oil has the potential to increase the quality of the fuel. The pre- and post-transesterification processes are essential in making the mixture. Moreover, it is important in determining properties such as viscosity, density, calorific value, and flash point. The results of this study indicated that the decrease of viscosity, density, flash point, and the increase of calorific value were due to the structural change in fatty acid in the mixture.

Keywords: *Jatropha*; waste cooking oil; biodiesel mixture; biodiesel properties.

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Introduction

Vegetable oil is one of the solvable energy sources used as alternatives to fossil fuel. However, it may not be appropriate in engines due to its high viscosity. To overcome the problem, the process transesterification can be used to decrease its viscosity [1].

One source of biodiesel is *Jatropha curcas* [2], a non-edible plant with no effect on food supply. *Jatropha* plants were generally found and used in most tropical and subtropical regions of the world. These plants grow fertile in poor conditions, resistant to drought, and can grow in marginal soils [3]. *Jatropha* has been identified as the main source of biodiesel from non-edible raw materials in developing countries such as Indonesia, Malaysia, and India [4]. Its oil is one of the prospective biodiesel feedstocks with high viscosity. This is due to the fact that its main constituent comprises of long chain unsaturated fatty acids. The use of transesterification process alone is not adequate when it comes to decrease the viscosity. Alternatively, mixing *Jatropha* oil with petrol diesel gives better results [5]. Conversely, there are problems associated with the disposal of used cooking oil because it pollutes the water environment. Therefore, it is safely disposed or utilized in such a way that it is harmless to human beings [6]. Used cooking oil mainly composes of short-chain saturated fatty acids. The use for biodiesel feedstock is one of the efforts for recycling waste, and it is a much cheaper raw material [7]. The biodiesel has several advantages, for example, it is biodegradable, non-toxic, less emission producer, high lubricity, and higher flash point [8]. Nevertheless, it must comply with some quality parameters to compete commercially.

Several researches carried out previously focused on increasing biodiesel properties using some mixture. For instance, Sarin *et al.* mixed *Jatropha*, palm, and pongamia [9] while other researchers used rubber seed and palm [10], soybean, cottonseed, and castor [11]. Making a mixture helps in improving biodiesel properties. For example, addition of cooking oil decreases the viscosity of *Jatropha* oil. This is because it changes the fatty acid structure, and this leads to new properties. To comply with a specified standard, biodiesel may depend on fatty acid compositions [12]. Unfortunately, most of the studies on the mixture of various biodiesel types only focus on feedstock and not fatty acid compositions [13]. Mixed vegetable oil produced a nonlinear composition consisting of fatty acids [14]. The objective of this study, therefore, was to determine the effect of mixture of waste cooking oil on properties of *Jatropha* biodiesel. The studied properties were density, viscosity, flash point, and calorific value. It was also aimed at determining the influence of how to mix biodiesel raw materials before and after transesterification.

Materials and Methods

This research used *Jatropha* and waste cooking oil as samples of the mixture prepared using two methods. The first one involved mixing *Jatropha* and waste cooking oil and processing the mixture to biodiesel. The second method involved processing pure oil to biodiesel and mixed the products of both oil types.

In the first method, *Jatropha* and waste cooking oils were mixed for a period of 60 minutes at a temperature of 90°C. Mixing was conducted with a heater and stirrer. Compositional ratios of *Jatropha* oil mixture and waste cooking oil were 100:0 to 0:100 with 10% increment. Furthermore, esterification process was conducted with the variations. This mixed oil reacted with 99% methanol at a 22.5% of oil volume and 18 M sulfuric acid (H_2SO_4) at a 0.5% of oil volume at 60°C and was stirred for 60 minutes.

Transesterification process was carried out using methanol (15% of oil volume) and potassium hydroxide (KOH) (1% of oil volume as catalyst). The mixture was stirred for 60 minutes at 60°C. After the transesterification process was completed, the mixture was deposited at the separator for about 8 hours, which resulted in a separation between biodiesel and glycerol with the latter removed from the bottom layer.

Furthermore, biodiesel washing was conducted using water heated above the boiling point of methanol (> 65°C). This process was useful for removing contaminants present in biodiesel. In addition, the drying process was carried out by heating the oil at 100°C for 10 minutes. This was useful for removing the remaining water content after the washing process.

In the second method, each pure oil was transesterified into biodiesel. The transesterification technique was the same as the one used in the first method. This process produces *Jatropha* biodiesel and used cooking oil biodiesel. Furthermore, both types of biodiesel were mixed with variations in composition as in the first method. This process produced *Jatropha* and waste cooking oil biodiesel. Furthermore, both types of biodiesel were mixed with variations in composition as in the first method. Mixing was carried out for 60 minutes at 60^{o}C.

The additional processes were to test biodiesel properties, which included density, viscosity, flash point, and calorific value. Density and viscosity were measured at 40°C.

Results and discussion

The compositions of fatty acid of *Jatropha* and waste cooking oil were shown in Table 1. *Jatropha* oil contains cis-11,14,17-eicosatrienoic

Table 1. Content of fatty acid of *Jatropha* oil and waste cooking oil (%).

Fatty Acid	Abbreviation	*Jatropha* Oils	Waste Cooking Oils
Methyl Butyric	C4:0	-	14.74
Methyl Tetradecanoic	C14:0	-	0.75
Methyl Palmitic	C16:0	1.2	35.90
Methyl Octadecanoic	C18:0	-	3.18
Cis-9-Oleic Methyl ester	C18:1	9.82	36.51
Lenolelaidic Acid Methyl Ester	C18:2	1.42	-
Methyl Lenolenic	C18:3	-	7.28
Methyl Arachidic	C20:0	-	0.39
Methyl Cis-11-eicocenoic	C20:1	-	0.30
cis-11,14,17-eicosatrienoic acid methyl ester	C20:3	87.19	-
Methyl Docosanoic	C22:0	-	0.36

Table 2. Properties of diesel fuel, *Jatropha* oil, and waste cooking oil.

Properties	Diesel[a]	*Jatropha* Oils	Waste Cooking Oils
Density ,40°C (kg/m^3)	830.00	937.74	893.29
Kinematic Viscosity ,40°C (cSt)	3.53	193.55	56.16
Flash Point (°C)	69.00	309.67	305.33
Calorific Value (MJ/kg)	43.80	37.16	38.56

[a] [7, 15]

acid methyl ester and cis-9-oleic methyl ester while waste cooking oil contains butyric methyl, palmitic methyl, cis-9-oleic methyl ester. Transesterification did not change fatty acid compositions from the feedstock.

Table 2 showed the properties of standard commercial diesel fuel [7, 15], *Jatropha* oil, and waste cooking oil. *Jatropha* oil demonstrated a higher density, viscosity, and flash point than that of cooking oil, while its calorific value was lower than that of cooking oil.

Density
The amount of mass of fuel that can be injected into the combustion chamber depends on the density of the fuel. Furthermore, the ratio of fuel air (AFR) and the energy content of the fuel entering a combustion chamber is influenced by the density of the fuel. The density of the oil mixture is influenced by the degree of unsaturation. The higher the degree of unsaturation of an oil, the higher its density [16]. The longer the carbon chain, the larger the size of the molecule, which causes higher density [17].

The density of each variation of biodiesel mixture was shown in Figure 1. The density of *Jatropha* biodiesel was 907.4 kg/m^3 while the density of used cooking oil biodiesel was 861.99 kg/m^3. *Jatropha* oil has fatty acids with double bonds and long carbon chains. This causes the high density of *Jatropha* biodiesel to decrease with the increasing mixture of used cooking oil biodiesel. Mixed density drops linearly from 100% *Jatropha* biodiesel to 100% used cooking oil biodiesel. Both mixing methods gave almost the same density results.

Viscosity
Viscosity is an important property because it influences the ability of fuel sprayer. High viscosity causes bigger particle size, constraint of sprayer, and narrow sprayer injection angle [18]. Unsaturation level and long fatty acid chain affect viscosity. Basically, longer carbon chain and lower unsaturation level lead to higher

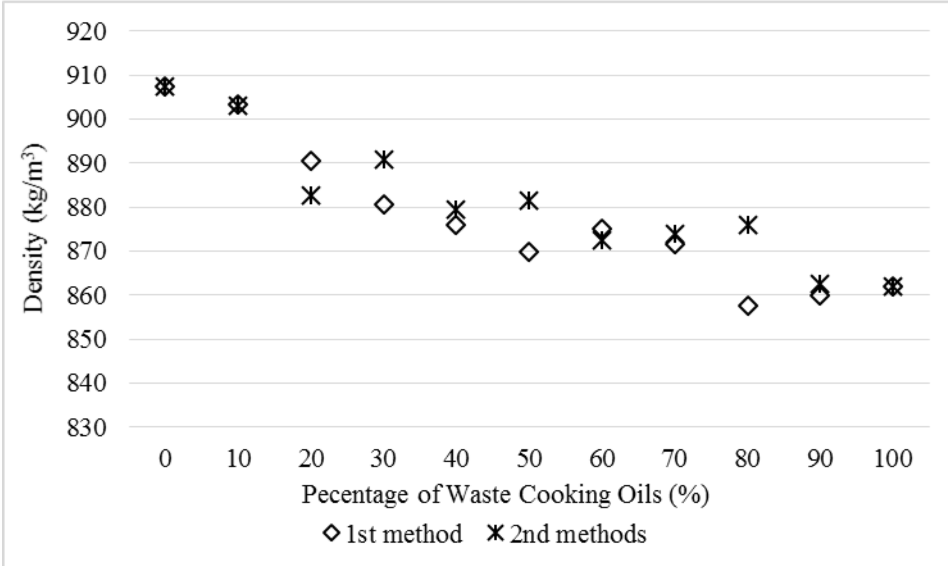

Figure 1. Density of biodiesel mixture of *Jatropha* seed oil and waste cooking oil.

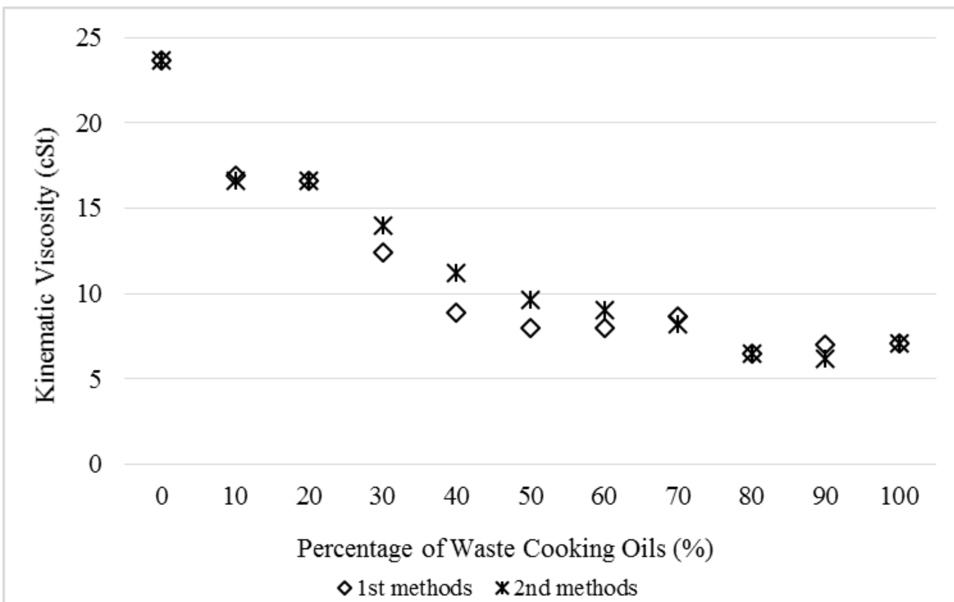

Figure 2. Viscosity of biodiesel mixture of *Jatropha* seed oil and waste cooking oil.

viscosity [16]. Molecular weight has higher effect on viscosity than saturation level [19].

The viscosity of waste cooking oil biodiesel at temperature of 40°C was 7.1 cSt. Biodiesel of *Jatropha* oil showed a relatively higher viscosity of 23.65 cSt at 40°C, which was greater than viscosity of biodiesel of waste cooking oil. This was because the *Jatropha* oil's fatty acid carbon chain was longer than that of cooking oil. Furthermore, the viscosity of the biodiesel mixture decreased with an increase of the composition of used cooking oil. Figure 2 showed that the mixture of *Jatropha* and waste cooking

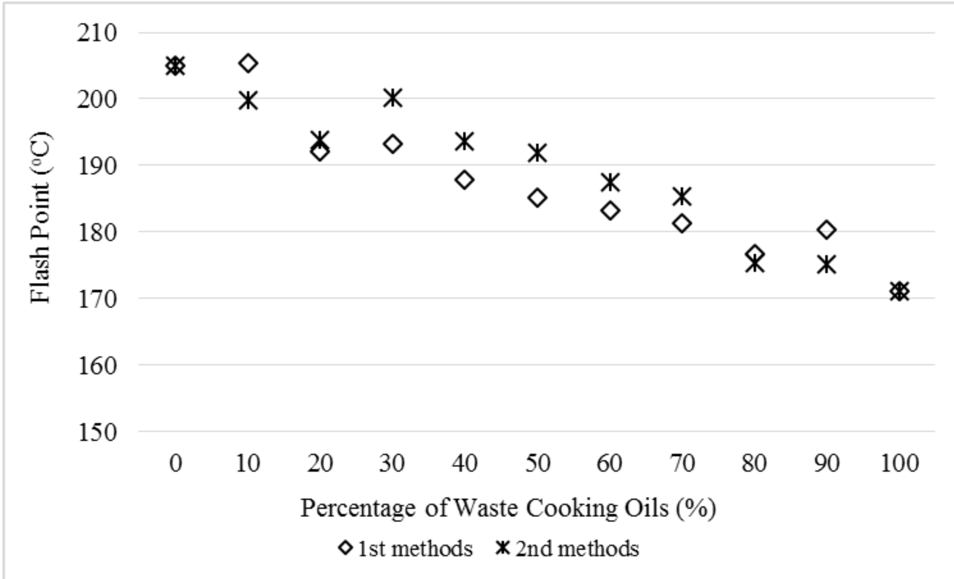

Figure 3. Flash point of biodiesel mixture.

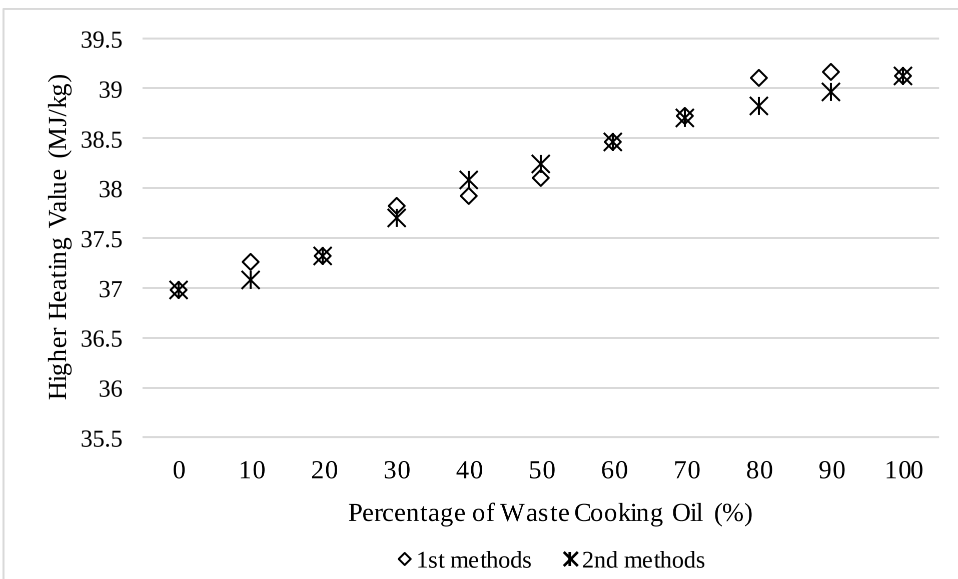

Figure 4. Calorific value of biodiesel mixture.

oil in the ratio of 90%:10% decreased viscosity by 28.4%, while a ratio of 70%:30% showed a viscosity decrease of 47.6%. In ratios of further compositions, viscosity values were relatively constant. The mixture methods used before and after transesterification produced nearly equal results.

Flash point

Flash point is one of the biodiesel properties for standard safety in transportation and storage. It is affected by fatty acid structure [20]. Figure 3 indicated that the flash point of biodiesel of waste cooking oil was lower than the flash point of biodiesel of *Jatropha* seed oil. Biodiesel of waste cooking oil showed flash point of 171.2°C, while the flash point of biodiesel of *Jatropha* seed oil was 205.1°C. Mixing of biodiesels of waste cooking and *Jatropha* seed oil decreased the flash point, though in a manner relatively linear to the mixture compositions. The two mixing methods did not give very different flash point results.

Calorific Value

The standard measurement of energy content is calorific value, which is lower in vegetable oil than it in diesel due to high oxygen content. The low calorific value of biodiesel decreases the engine power and, as a consequence, increases the fuel consumption. The higher fatty acid content with double bonds in carbon chain (C=C) lowered the calorific value of biodiesel [16].

Figure 4 demonstrated that biodiesel of waste cooking oil showed higher calorific value (39.14 MJ/kg) than that of *Jatropha* oil (36.98 MJ/kg) due to higher fatty acid with double bonds in biodiesel of the *Jatropha* seed oil. The biodiesel mixed with waste cooking oil showed a higher calorific value. The mixed biodiesel of *Jatropha* seed and waste cooking oil increased the calorific value due to change in their compositions. The two methods of biodiesel mixing gave results nearly equal in the calorific value.

Conclusions

Jatropha and waste cooking oil have different fatty acid structures, and this influenced the mixed biodiesel. Mixing these oils, therefore, causes a change in the properties. The results showed that the mixing method of biodiesel before and after the transesterification reaction yielded almost the same results in the properties of mixed biodiesel. This showed that the two mixed methods produced similar fatty acid composition.

To improve the quality of *Jatropha* oil biodiesel, it should be mixed with used cooking oil. The results showed a decrease in viscosity and density when this approach was used. There was also a decrease in the flash point which was still above the permitted limit. The calorific value also increased with an increase in waste cooking oil percentage. Therefore, this method is quite efficient for improving the quality of biodiesel. Further research needs to be carried out with a variety of transesterification processes.

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