# PRELIMINARY STUDY OF MIXING USED COOKING OIL AND LEMON PEEL ESSENTIAL OIL AS AN ALTERNATIVE FUEL TO REPLACE BIODIESEL

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## ABSTRACT

Biodiesel is an environmentally friendly renewable bio-energy with many advantages over diesel fuel. The disadvantage of biodiesel is that the price is still relatively expensive so it cannot compete with diesel fuel. This high price is due to the high cost of raw materials and manufacturing process costs. Raw materials such as palm oil, methanol and methyl acetate are expensive, and the transesterification and interesterification processes require long process stages that require a lot of energy supply. The solution to overcome this problem is to use cheap raw materials and a simple manufacturing process. Used cooking oil is household waste that has prospects as a raw material. Another ingredient used is lemon essential oil. Lemon essential oil can be made yourself by extracting lemon peel waste using a boiling or steaming process. The lemon essential oil used is also small, namely a maximum of 5% of the mass of used cooking oil. It is hoped that mixing used cooking oil with lemon essential oil can replace biodiesel. Lemon essential oil is a bio-additive that can improve the quality of used cooking oil to approach the physical properties of biodiesel. With this new process, it is hoped that it can produce fuel that is cheap but of good quality. The aim of the research is to obtain a new fuel to replace biodiesel that is cheaper and more efficient, namely with cheap raw materials and fewer process stages so that it will reduce production costs. The research began with the activation of zeolite as an adsorbent for purifying used cooking oil with variables including zeolite mass of 400 grams, calcination temperature of 300$^0$C, activation time of 2 hours and zeolite size > 80 mesh. The second stage of the research was purifying used cooking oil with zeolite using a variable volume of 3 liters of used cooking oil and a purification time of 1 hour. The third stage of the research was mixing purified used cooking oil with lemon essential oil with variable volume of essential oil (3, 4, 5, 6, 7% oil volume) and mixing temperature (30, 40, 50$^0$C), mixing time 60 minutes, stirring speed 500 rpm and oil volume 150 mL. After the mixing time and the sample temperature reached room temperature, an analysis of the density, acid number, viscosity and FFA of used cooking oil with bio-additive lemon essential oil was carried out. The analysis results are compared with the biodiesel standard SNI 7182-2015 to see whether the product/sample approaches the physical properties of biodiesel.

**Keywords:** biodiesel; expensive; used cooking oil; lemon essential oil; fuel.

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## INTRODUCTION

The need for petroleum as the main energy source continues to increase along with population growth and technological advances. The need for fuel oil still depends on petroleum, where the availability of petroleum itself is becoming increasingly scarce and petroleum is non-renewable oil. To overcome this, efforts are being made to look for other renewable energy sources [1]. Materials that can be used to replace fossil fuels are biodiesel from vegetable oils and animal oils.

Biodiesel can be made by degumming, esterification, transesterification, interesterification or hydrogenation processes using a catalyst. The transesterification process for making biodiesel costs much more than making diesel fuel, so the price of biodiesel also becomes more expensive [2]. To overcome this, an alternative can be used, namely adding bioadditives in the form of aromatic compounds to the oil. Vegetable oil cannot be used directly as fuel in diesel engines because of its high viscosity. High viscosity results in a long evaporation process and damage to the engine, therefore bioadditives are added to reduce the viscosity of the vegetable oil [3]. Used cooking oil is used frying oil that has been used many times. Cooking oil that has been used and through the heating process will experience changes in physical and chemical properties which will produce fatty acid and glycerol components from the triglyceride hydrolysis reaction. The free fatty acid content in the oil will increase with the length of the heating process. The viscosity of used cooking oil also becomes higher due to the formation of dimers, acid polymers and glycerides due to the heating process [4].

Used cooking oil can be used as raw material for biodiesel after first being purified using adsorbents through a physical adsorption process. However, because the process of making biodiesel is quite expensive, researchers are trying to identify methods to reduce production costs. The first way is to use heating, mixing and microemulsifying vegetable oil to reduce its viscosity. From studies that have been carried out mixing vegetable oil-diesel fuel, vegetable oil-alcohol fuel, vegetable oil-alcohol-diesel fuel, it shows that the viscosity of vegetable oil decreases to that of diesel fuel [2]. The addition of aromatic compound bioadditives can reduce the viscosity of vegetable oil so that the oil can be used as fuel. According to research that has been conducted, mixing vegetable oil with eucalyptus oil can reduce the viscosity and lower the flash point of palm oil. The decrease in viscosity in vegetable oils is caused by intermolecular attraction forces in essential oils and vegetable oils. Oil that has been mixed will have molecules that can move more dynamically because of the forces that occur. Meanwhile, vegetable oils which have a high flash point can also be lowered by adding essential oils because aromatic compounds which are triglyceride molecules can weaken the bonds. In the evaporation process, molecules must reach a surface in order to evaporate before combustion. The lower the flash point temperature, the easier the evaporation and combustion processes take place [5]. The addition of essential oil from lemons is also done to improve the quality of the purified oil so that it can be used as fuel [4]. Apart from reducing viscosity, lemon essential oil mixed into biodiesel also acts as an antioxidant. Lemon essential oil is known to have natural antibacterial and antioxidant properties [6]. This can help biodiesel to reduce the possibility of free fatty acid formation, due to its antioxidant properties. So when fatty acids are not formed, the quality of biodiesel will also be better. Lemon essential oil has a density of 0.853 kg/L [6]. The density of lemon essential oil can affect the density of biodiesel. If the density of biodiesel is above lemon essential oil, then mixing the two can cause the density of biodiesel to decrease, and vice versa. This is also proven by previous research where density measurements were carried out on B20 biodiesel, the density of which was lower than the density of lemon essential oil. After the two are mixed, the density of the mixture will increase because lemon essential oil has a higher density than B20 biodiesel [6].

This research aims to analyze fuel using purified used cooking oil as raw material and adding essential oil from lemons. The addition of essential oil from lemon peel aims to reduce the high viscosity of used cooking oil. Apart from that, essential oils can help reduce flash points in used cooking oil. Essential oils mixed into used cooking oil can change the characteristics of used cooking oil so that used cooking oil can meet the criteria for engine fuel [5]. With this research, it is hoped that it can meet the need for fuel oil and reduce dependence on imported fuel oil, as well as overcome environmental pollution caused by used cooking oil.

## MATERIALS AND METHODS

### Tools and Materials

Tools used: 80 mesh sieve, beakerglass, burette, desiccator, *Erlenmeyer*, hot plate, magnetic stirrer, oven, pycnometer and viscometer. Ingredients used: distilled water, ethanol 95%, $H_2SO_4$ 0.1 N, phenolphthaline indicator, KOH 0.1 N, lemon essential oil (limonene content: 40 – 60%; max citral content 35%), used cooking oil and zeolite natural.

### Experimental Procedures

### Pre-treatment and Activation of Natural Zeolites

Reduce the size of the zeolite to a size of 80 mesh and immerse the zeolite in $H_2SO_4$ solution at a concentration of 0.1 N for 90 minutes. Wash the zeolite using distilled water. Heat the zeolite using an oven at 300℃ for 2 hours.

### Used Cooking Oil Refining Process

Prepare 150 mL of used cooking oil, then settle it on the used cooking oil. The deposition results were added with zeolite as an adsorbent for the purification process using a magnetic stirrer for 1 hour with a rotation speed of 500 rpm. After 24 hours, it is filtered using filter paper to separate the used cooking oil from the zeolite. Carry out characteristic analysis of the results of refining used cooking oil, namely density, viscosity, water content and acid number tests.

### The Process of Adding Lemon Essential Oil to Purified Used Cooking Oil

Add 150 mL of lemon essential oil to used cooking oil that has been purified with a concentration according to the specified variables. Mix lemon essential oil with a heating temperature according to the specified temperature variable for 60 minutes with a stirring speed of 500 rpm. Carry out tests on the results of the essential oil mixing process, namely testing the acid number, density, viscosity, water content and FFA of the oil.

### Test Water Content

Oven the empty evaporating cup at a temperature of 105-110°C for 30 minutes then transfer to a desiccator. Once cool, the evaporating cup is weighed to obtain the weight of the empty container. Put 5 grams of sample into an evaporator cup then bake at 105-110°C for 30 minutes. Cool the heated sample in a desiccator then weigh it to a constant weight. Repeat the steps above three times. Water content calculation with equation (1):

$$\text{Water content } = \frac{\text{weight of filled cup} - \text{weight of empty cup}}{\text{weight of empty cup}} \text{ x } 100\% \tag{1}$$

### Density Test [8]

Weigh the pycnometer empty to obtain the empty weight of the pycnometer. Insert the sample into the pycnometer until it is full and then close the pycnometer, making sure no bubbles form. Weigh the pycnometer containing the sample to a constant weight. Repeat the steps above three times. Density (ρ) calculation with equation (2):

$$\text{Density } = \frac{\text{weight of filled pycno} - \text{weight of empty pycno}}{\text{volume of pycnometer}} \tag{2}$$

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## Viscosity Test

### a. Tool Calibration

Setting up the Oswald viscometer. Fill the viscometer with aquadest to the upper limit mark. Close the hole in the tube with the boundary mark then remove the distilled water from the tube without the boundary mark up to half a ball. Remove the hole cap from the tube then count the aquadest time from the top mark until it passes the predetermined bottom mark. Repeat the steps above three times.

### b. Sample Viscosity Test

Setting up the Oswald viscometer. Fill the viscometer with sample to the specified upper limit mark. Close the hole of the tube with the boundary mark then remove the sample from the tube without the boundary mark until it is half spherical. Remove the hole cap from the tube then count the sample time from the top mark to passing the specified bottom mark. Repeat the steps above three times. Liquid viscosity calculation with equation (3):

$$\eta 1 / \eta 2 = (\rho 1 \times t1) / (\rho 2 \times t2) \quad (3)$$

Where:
$\eta 1$ = sample viscosity
$\eta 2$ = distilled water viscosity
$\rho 1$ = sample density
t1 = sample time
$\rho 2$ = density of distilled water
t2 = distilled water time

## Test FFA Levels and Acid Number [8]

Weigh 5 grams of sample in an *Erlenmeyer* then mix it with 95% ethanol. Heat the sample mixture with 50 mL ethanol for 10 minutes until it boils on the hot plate while stirring occasionally. Cool the mixture for 10 minutes. Drip 5 drops of phenolphthalein indicator into the mixture. Titrate the mixture with 0.1 N KOH until the color changes to pink. Repeat the steps above twice. Calculation of FFA levels with equation (4) and acid number with equation (5):

$$FFA = \frac{N\ KOH x\ \ mL\ KOH\ x\ MW\ oleic\ acid}{m\ x\ 1000} x\ 100\%$$
(4)

$$Acid\ number = \frac{N\ KOH x\ \ mL\ KOH\ x\ MW\ KOH}{m}$$
(5)

Where:
N = KOH normality
MW = molecular weight
m = mass of sample
mL = volume of KOH during titration

## RESULTS AND DISCUSSIONS

### Test Water Content

From the research that has been carried out, a picture of the effect of the volume of essential oil on the water content of purified used cooking oil is obtained as follows:

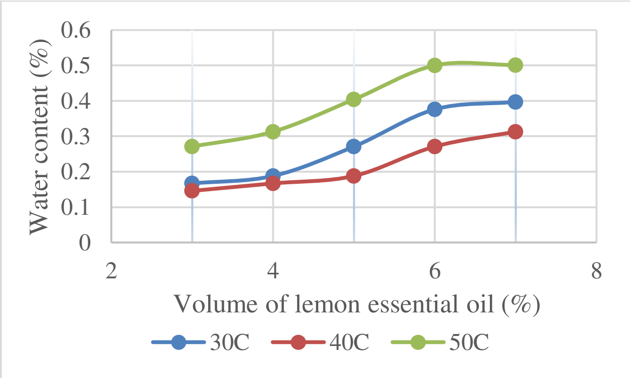


**Figure-1.** Effect of lemon essential oil volume (%) on water content (%) in used cooking oil.

The lowest water content is obtained by adding 3% of the total volume of essential oil at a temperature of 40°C, namely 0.146%. Meanwhile, the highest water content was obtained when adding 7% essential oil with a mixing temperature of 50°C, namely 0.501%. According to theory, the more volume of essential oil added to used cooking oil, the greater the water content in the used cooking oil. From the Figure-1 above, the results of the water content test show that the more volume of essential oil added, the greater the water content. The temperature variable in the water content test does not affect it because the temperature used is not the boiling point of water, so the water content in used cooking oil does not change.

### Density Test

After conducting research, the following image of the density test results was obtained:

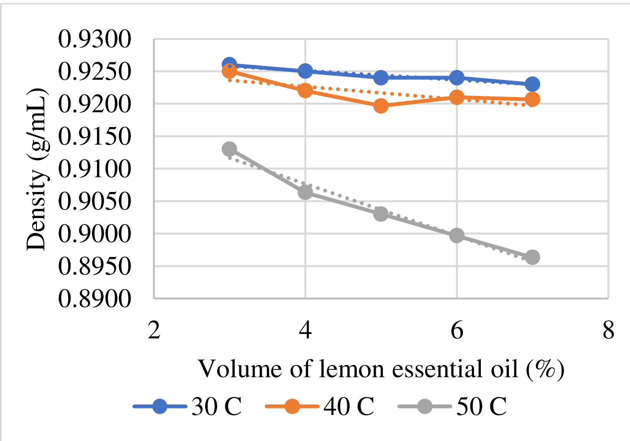


**Figure-2.** Effect of lemon essential oil volume (%) on the density of used cooking oil.

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The highest density of used cooking oil mixed with essential oil was obtained, namely when adding 3% essential oil with a heating temperature of 30°C, namely 0.9260 g/mL. Meanwhile, the smallest density was obtained by adding 7% essential oil at a temperature of 50°C, namely 0.8963 g/mL. From the Figure-2, it was found that the more essential oils added to used cooking oil, the lower the density obtained. The decrease was caused by the density of essential oils being lower than used cooking oil. The density of used cooking oil that has been obtained is 0.9490 g/mL while the density of lemon essential oil is 0.843 g/mL [9], so that the mixing process can reduce the density of the solution [7].

**Viscosity Test**

From the analysis that has been carried out, the viscosity results of used cooking oil that has been mixed with essential oils in the picture are as follows:

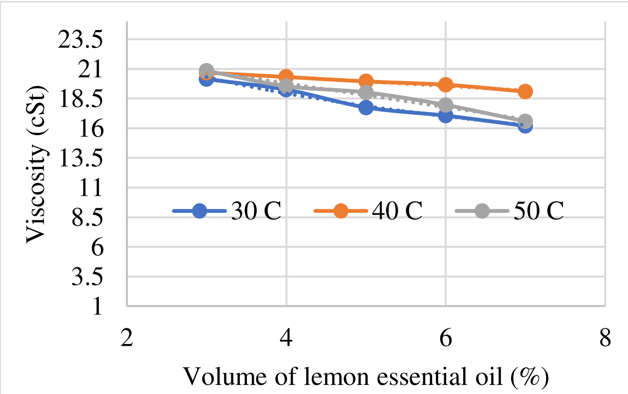


**Figure-3.** Effect (%) of lemon essential oil volume on the viscosity of used cooking oil.

The thinnest viscosity was obtained by adding 7% lemon peel essential oil from the total volume of used cooking oil and a mixing temperature of 30°C, namely 14.9006 cP or 16.1963 cSt. Meanwhile, the thickest is obtained by adding 3% essential oil with a mixing temperature of 50°C, namely 19.1749 cP or 20.8423 cSt. From the Figure-3 above, it can be concluded that the more essential oil added to used cooking oil, the lower the viscosity. This is in accordance with previous research, where the more essential oils added, the lower the viscosity. According to previous research, coconut oil that is given additives will experience a decrease in viscosity. Coconut oil that is added with aromatic additives of 250 - 1250 ppm will decrease its viscosity to approximately 19 - 20 cSt [2].

**FFA Test and Acid Number**

Comparison of the results of used cooking oil with used cooking oil that has been mixed with essential oils. First, we analyzed the used cooking oil from the purification first and obtained %FFA of 1.80% and an acid number of 3.5 mg KOH/g sample. The results of the %FFA analysis of used cooking oil that has been mixed with essential oils are as follows:

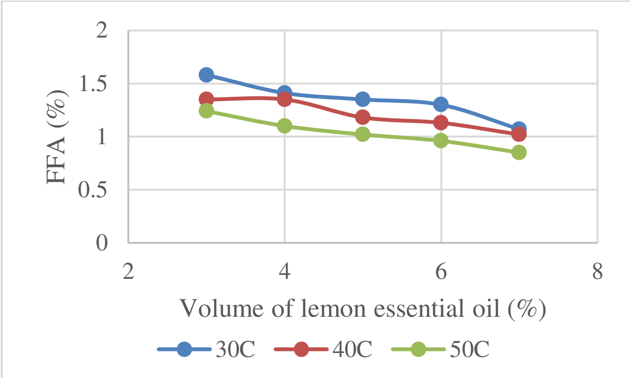


**Figure-4.** Effect of lemon essential oil volume (%) on FFA (%) in used cooking oil.

From the Figure-4 above, the %FFA content was obtained when adding 7% essential oil at temperatures of 30°C and 40°C, the same value was obtained, namely 1.02%, and the lowest FFA content was obtained at a temperature of 50°C with the addition of 7% essential oil, namely 0.85%. Theoretically, the more essential oils mixed into used cooking oil, the lower the %FFA will be. The acid number obtained can be seen from the analysis and calculations that we have carried out, and the results obtained are as follows:

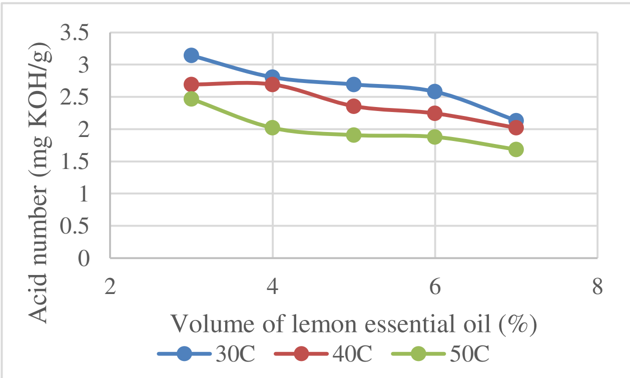


**Figure-5.** Effect of lemon essential oil volume (%) on the acid number of used cooking oil.

From the Figure-5, the lowest acid number is obtained at a temperature of 50°C with the addition of 7% essential oil with an acid number of 1.683 mg KOH/g sample. When adding 7% essential oil at temperatures of 30°C and 40°C, the acid number is obtained: 2.1318 and 2.0196 mg KOH/g sample. The addition of lemon peel essential oil can reduce the acid number of purified used cooking oil. According to theory, the more essential oils used, the more the acid number will decrease because essential oils act as antioxidants [10].

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## CONCLUSIONS

From the research that has been carried out, it can be concluded that the effect of essential oil volume and temperature on used cooking oil is: In the water content test, the variable with the lowest water content was obtained, namely the addition of an essential oil volume of 3% and a temperature of 40°C with a water content of 0.146%. This shows that the research results are not in accordance with the SNI biodiesel standard 7182-2015, namely 0.05% by volume. The density test results of adding a volume of 7% essential oil at a temperature of 50°C with a density of 0.8963 g/mL are the closest to SNI 7182-2015. This shows that the research results are not in accordance with the SNI biodiesel standard, namely 0.89 g/mL. In the viscosity test, the variable with the viscosity closest to SNI was obtained, namely the addition of 7% essential oil volume at a temperature of 30°C with a viscosity of 16.1936 cSt. This shows that the research results are not in accordance with the SNI biodiesel standard, namely 2.3 - 6.0 cSt. In the acid number test, the variable with the acid number closest to SNI was obtained, namely the addition of 7% volume of essential oil at a temperature of 50°C with an acid number of 1.683 mg KOH/g sample. This shows that the research results are not in accordance with the SNI biodiesel standard, namely 0.5 mg KOH/g sample.

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