# Purification of Waste Cooking Oil as Biodiesel Feedstock Using Ceramic Filter

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# Purification of Waste Cooking Oil as Biodiesel Feedstock Using Ceramic Filter

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**Abstract**

The obstacle of biodiesel preparation from waste cooking oil (WCO) is mainly caused by the high content of free fatty acids (FFAs) in the sample. The high concentration of FFAs in biodiesel feedstock often leads to soap formation and difficulty of product separation. In this experiment, WCO was filtrated using a ceramic filter to reduce FFAs before being converted to biodiesel. Ceramic filters were made using natural clay, diatomite, and an iron powder mixture in various compositions. The effect of contact time and ceramic filter composition on flux was investigated. Temperature and flow rate of WCO were set at 40°C and 1.5 L/min, respectively. The results showed that FFAs concentration was decreased from 12% to 0.003% using ceramic filter with the composition of 69% natural clay, 30% diatomite, 1% iron powder, and contact time of 90 minutes. The results also showed that palmitic acid and oleic acid concentration decreased to about 1.5 and 4%, respectively. The results will contribute to the application of ceramic filter as the pretreatment for biodiesel feedstock with high concentrations of FFAs.

**Keywords**: Biodiesel, ceramic filter, diatomite, free fatty acid, microfiltration

## Introduction

The energy consumption is rapidly increasing in the world. Crude oil is the main source of fossil energy being consumed by the world's population which has been exceeding other types of energy source. The abundant use of oil reserves leads to severe problems for humanity. The concerns for security of fossil fuel supply and the environmental problem such as global warming (Atadashi, 2015) are given by the increasing amount of $CO_2$, which resulted from the combustion of fossil fuel. The dependence on petroleum based oil can be reduced by providing alternative fuels such as biodiesel, bioethanol, and biogas.

The biodiesel raw materials containing free fatty acids (FFA) such as non–edible crude oils, waste food oils, animal fats, and byproducts of the refining vegetable oils, are preferred for substitution of petroleum based diesel fuel (Enweremadu and Mbarawa, 2009). The waste cooking oil (WCO) is a promising feedstock for biodiesel because it is a cheaper raw material and can be collected from large–scale food processing (Bautista et al, 2009). Consequently, biodiesel production cost might be reduced by 60 to 90% when WCO is employed as feedstock. However, most of biodiesel feedstock such as Mahua (Ghadge and Raheman, 2005) have a high FFAs (19%) content, which is categorized as brown grease of the WCO (Kiakalaieh, *et al.*, 2013). The FFAs in the WCO will react with the base catalyst to form soap, which leads to loss of catalyst and ester product, and increasing the production costs (Encinar, *et al.*, 2011). Thus, the single–step process involving an alkali–catalyzed trans–esterification is insufficient for high FFAs biodiesel feedstock. The undesirable compounds in the WCO can be avoided by a pretreatment of the used cooking oil such as steam injection, neutralization, vacuum evaporation and vacuum filtration (Araújo, *et al.*, 2013). In the current experiment, ceramic filter was utilized as a treatment process for biodiesel preparation using waste cooking oil.

## Experimental Methods

### *Material*

Ceramic filter was made by using a mixture of natural clay, diatomite and iron powder. Ceramic filter designed as porous tube that has an outer diameter 10 cm, an inner diameter of 7.5 cm and a length of 25 cm. Natural clay and diatomite dried naturally by sunlight for 12 hours and grinding into 20 mesh of particle size. Iron powder from the local welding shop is sieved to 500 micrometers of particle size. Materials used in ceramic filter production was homogenized with clean water, molded, dried at room temperature for seven days and sintered at 900 $^{o}$C for 12 hours in a local ceramic manufacturer. Two types of ceramic filter were designed in this experiment. The first type of ceramic filter which has a dominant composition of natural clay and the second type of ceramic filter contains diatomite as main component as shown in Table 1.

Table 1. Ceramic filter composition

| Ceramic Filters | | Natural clay (%wt) | Diatomite (%wt) | Iron powder(%wt) |
|---|---|---|---|---|
| Type 1 | A | 74 | 25 | 1 |
| | B | 79 | 20 | 1 |
| | C | 69 | 30 | 1 |
| Type 2 | D | 25 | 74 | 1 |
| | E | 20 | 79 | 1 |
| | F | 30 | 69 | 1 |

WCO sample was transferred into a storage tank using centrifugal pump and filtered using a ceramic filter. The filtration time was 90 minutes and the samples were taken at an interval of 15 minutes for FFA analysis. The XRD (PanAnalytical Empyrean) was used to characterize the diatomite components. The GC–MS (Agilent 6890N) with semi–polar column, which has a length of 30 m and a diameter of 250 μm was performed to determine the WCO compounds. The initial temperature of the sample being examined by GC–MS was 40°C and the maximum temperature was 325$^{o}$C. The Scanning Electron Microscope (JEOL–JSM6510 Japan) was performed to determine the surface morphologies of diatomite.

## Results and Discussion

### *Effect of ceramic filter composition*

Waste cooking oil was filtered using the ceramic filter to reduce the free fatty acid. Free fatty acid was adsorbed through two types of ceramic filters which are made from natural clay, diatomaceous earth, and iron powder. The concentrations of the FFAs in the WCO become an important factor in determining the quality of methyl ester as shown in Figure 1 and Figure 2, respectively. As can be seen, both the ceramic filter type could decrease the FFAs from WCO samples. As suggested, increase of contact time will decrease the percentage of FFAs in permeate. Among ceramic filter type 1, filter C was able to decrease the FFAs of WCO from 12 to 0.02% at contact time of 90 minutes. The results also showed among ceramic filter type 2 that Filter E able to decrease the FFAs up to 0.17%. However, the results show that the ceramic filter with dominant composition of natural clay is better compared to those of diatomite. A flux decline over the filtration time was attributed to the fouling of ceramic filter surface (Atadashi, 2015).

### *Effect of Ceramic Filter Composition to Flux*

Figure 3 shows the flux of permeate for type 1 ceramic filter. Among the ceramic filters tested the lowest flux was found as 0.04163 L/cm$^2$.min at 90 min of contact time was obtained using membrane C. The same observation was also found in Figure 4 using membrane E which flux decreases to 0.02082 L/cm$^2$.minand maximum flux occurs at contact time 90 min. It was suggested that flux decreased cause by fouling on the ceramic filter surface after 75 minutes of contact time.

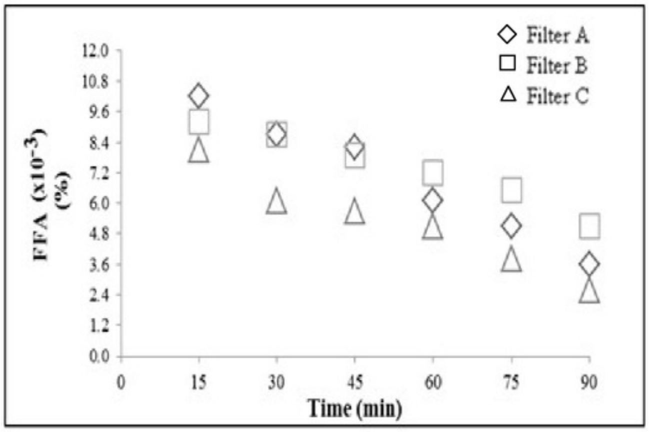


Figure 1. FFA quality using ceramic filter type 1

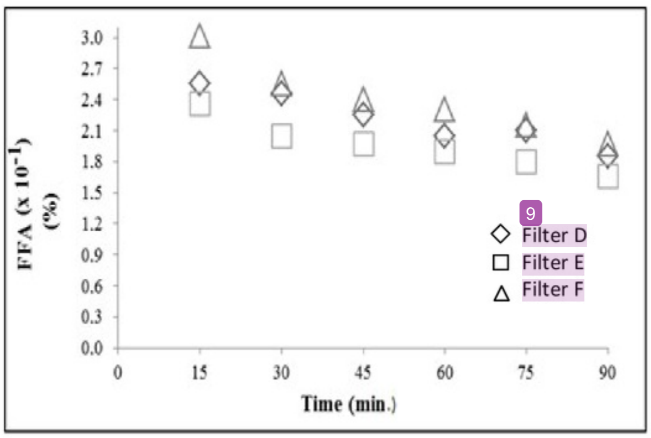


Figure 2. FFA quality using ceramic filter type 2

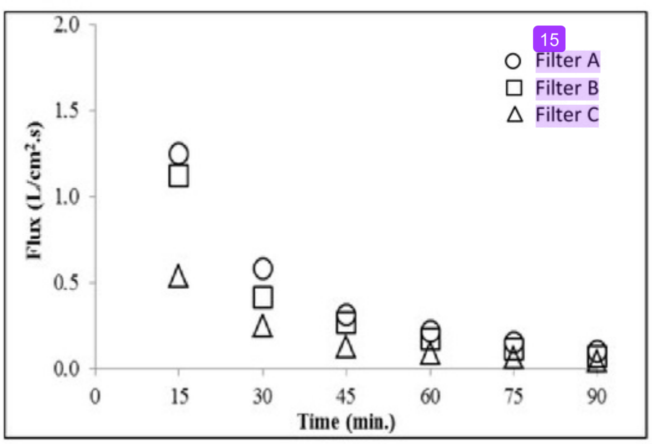


Figure 3. Flux of ceramic filter type 1

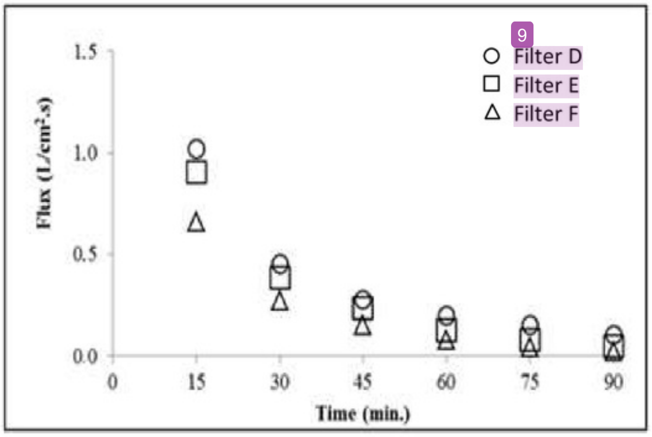


Figure 4. Flux of ceramic filter type 2

Figure 4 showed the permeate flux of ceramic filter type 2. The flux decline is rapidly decreased and the permeate flow rate is very low because the decrease in driving force and an addition in the hydraulic resistance of the membrane due to fouling, which may be done by excessive accumulation of particulates at the membrane surface or in the pores. Figure 3 shows the SEM image of typical diatomite from Baturaja, South Sumatra. SEM analysis of diatomite showed that the major compound of diatomite were silica, aluminium, potassium and other impurities.

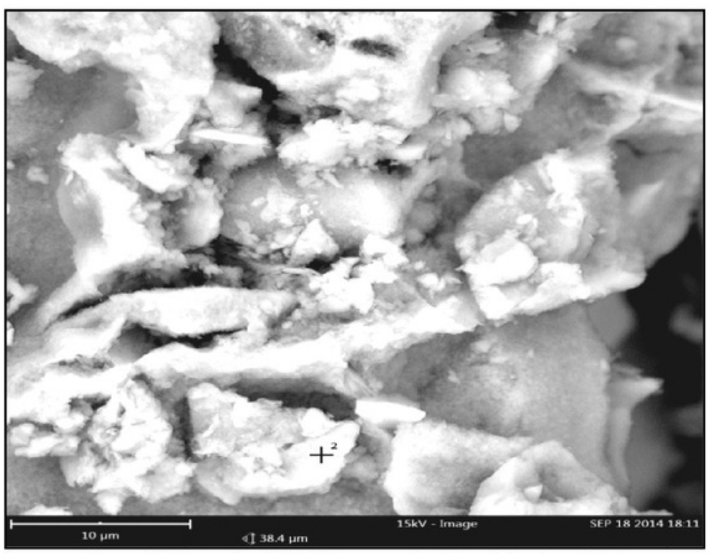


Figure 5. Diatomite SEM Micrographs (Magnification 500x)

Figure 6 shows the XRD pattern of diatomite from Baturaja, South Sumatra, Indonesia. In such area, the application of diatomite has been mostly just as an abrasive for cleaning household appliances. From XRD analysis, it was found that the main compounds of diatomite are 85.72% sillimanite ($Al_2O_5Si$) and 14.28% cristobalite ($O_2Si$). The pore size of diatomite was in the range of 0.02 µm to 20 µm that indicated this material is suitable for microfiltration process using ceramic filter.

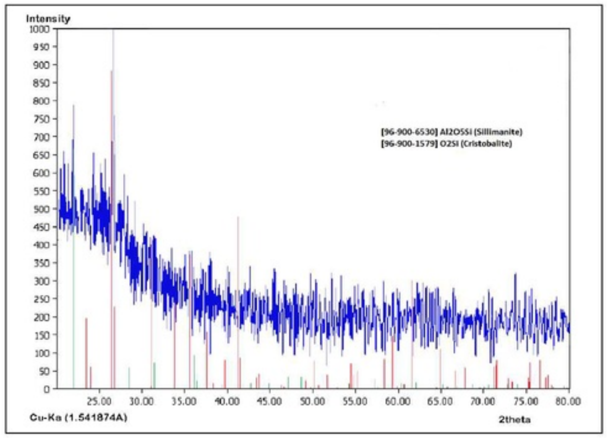


Figure 6. XRD pattern of Diatomite

In the current work, waste cooking oil compounds were analyzed using a GC–MS. The chromatograms of WCO can be seen in Figure 7 and Figure 8. The GC–MS results show that palmitic acid concentration is decreased from 48.70 % (before filtration) to 47.46 % (after filtration using ceramic filter).

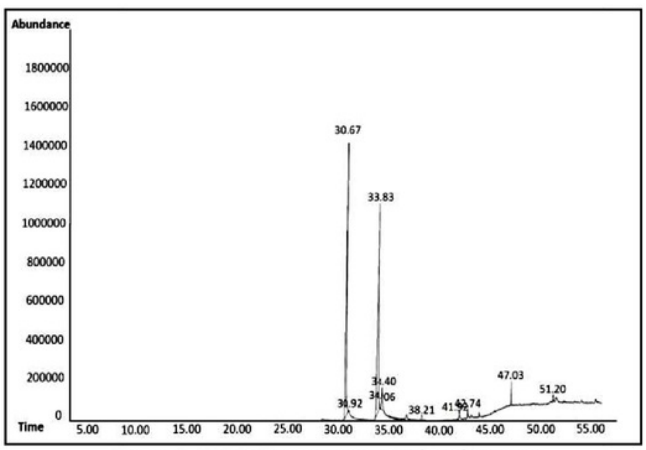


Figure 7. WCO Chromatogram before filtration

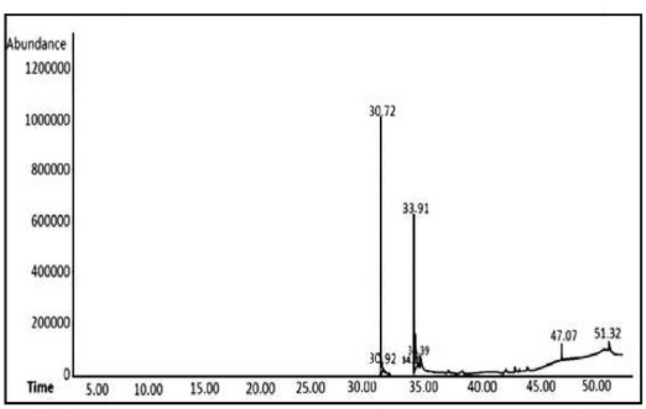


Figure 8. WCO Chromatogram after Filtration Process

Figure 8 showed that ceramic filter was able to decrease Palmitic acid and Oleic acid in the WCO. However, it was suggested that ceramic filter can reduce the others small compounds from WCO such as linoleic acid and phospolipid.

## Conclusions

The best ratio of ceramic filter composition among clay, diatomite, and iron powder is 69%: 30%: 1%, which is can reduce the free fatty acid compund in waste cooking oil from 12% to 0.03% in 90 minutes of contact time. However, flux will significantly decreased after 45 minute of contact time. Methyl ester which can be produced by waste cooking oil through the ceramic microfiltration filter has 90.6% of purity. ceramic filter can be used as pretreatment for methyl ester production to replace the esterification process.

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