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Conversion of Waste Cooking Oil into Biodiesel

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Abstract: Waste cooking oil (WCO) has become one of the major environmental pollutants due to its improper disposal, thus putting the ecosystem at risk. Therefore, this study aims to produce biodiesel through the transesterification process of WCO and elucidate its chemical and physical properties. Sodium hydroxide is the catalyst for this process, was dissolved in methyl alcohol before being mixed with WCO. The WCO and methyl alcohol mixture was left for a day and was then filtered and washed to obtain pure biodiesel. Results shows that the biodiesel produced from WCO has almost identical properties with biodiesel produced from other sources in terms of density and kinematic viscosity which are 0.85 kg/m^3 and 5.76 mm^2/s respectively. Fourier Transform Infrared spectroscopy spectrum analysis of biodiesel from WCO also shows similar functional groups being present in other biodiesels which contains C-O, C=O and C-H at 1168 cm^{-1}, 1741 cm^{-1}, and 2922 cm^{-1} respectively. Therefore, WCO can be used as an alternative source to produce biodiesel. Glycerin, the byproduct of biodiesel production is proposed to be further researched for its potential in producing other products in the pharmaceutical and cosmetics industry as well as soap production.

Keywords: Waste Cooking Oil, Biodiesel, Transesterification, Renewable Energy

1. Introduction

Biodiesel is made up of fatty acid alkyl esters that are formed when oils are transesterified with alcohol [1]. Soybean oil, animal fats, and other types of recycled cooking oil are used to make biodiesel, a vital fuel source. Biodiesel are considered a renewable energy source because of their dependability, combustion efficiency, and availability, as well as the fact that they mitigate the negative effects produced by non-renewable fossil fuel combustion. Biodiesel can be used as an alternative energy source in diesel engines due to its biodegradability and low emission of carbon and sulphur. When compared to petroleum diesel, biodiesel reduces carbon dioxide emissions by 50 to 78.45% [2].

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Chemical, biological, supercritical, and other processes can all be used to make biodiesel. Transesterification using acid or base catalysis is currently the primary industrial production technique [3].

Transesterification is a chemical process that converts triglycerides found in oils into biodiesel. In this process, an ester is combined with an alcohol. In the case of biodiesel, waste cooking oil (WCO), which is the ester, is combined with methyl alcohol, specifically methanol. Biodiesel is produced through the transesterification process has a substantially lower viscosity than petroleum diesel, making it suitable for use in diesel engines. To start a chemical reaction, a small amount of catalyst and methyl alcohol is added to the mix. The end products are methyl esters, which is the technical term for biodiesel, and glycerin, a byproduct of the chemical reaction. The biodiesel is ready to use once the transesterification process is completed. Glycerin is separated and can be used in cleaning products, cosmetics, and pharmaceuticals. Meanwhile, biodiesel is distributed locally for use in vehicles, machinery, farm equipment, and other applications.

WCO is the oil that remains after the deep-frying process and may be used to make biodiesel. Transesterification of vegetable, animal, or waste oil with short chain alcohols is the most common way to make biodiesel. WCO is abundant since humans all over the world consume it generally in their cooking. Most households, restaurants, catering establishments, and industrial kitchens generate liquid residues daily, particularly from the frying process. Collection of WCO for biodiesel production aims to reduce the environmental, infrastructure, and health risks associated with its improper disposal and reuse for food preparation. Generally, in this research, the WCO has been utilized to assess its capability of replacing fossil fuel-derived diesel by comparing its chemical and physical properties with biodiesel that are currently in the market with positive impact towards the environment. Therefore, this study aims to produce biodiesel from WCO and elucidate its physical and chemical properties.

2. Materials and Methods

The main materials used in this research was WCO, sodium hydroxide, and methyl alcohol. The WCO were collected from stalls located in Universiti Tun Hussein Onn Malaysia cafeteria. The general process flow of production of biodiesel from WCO is shown in **Figure 1**.

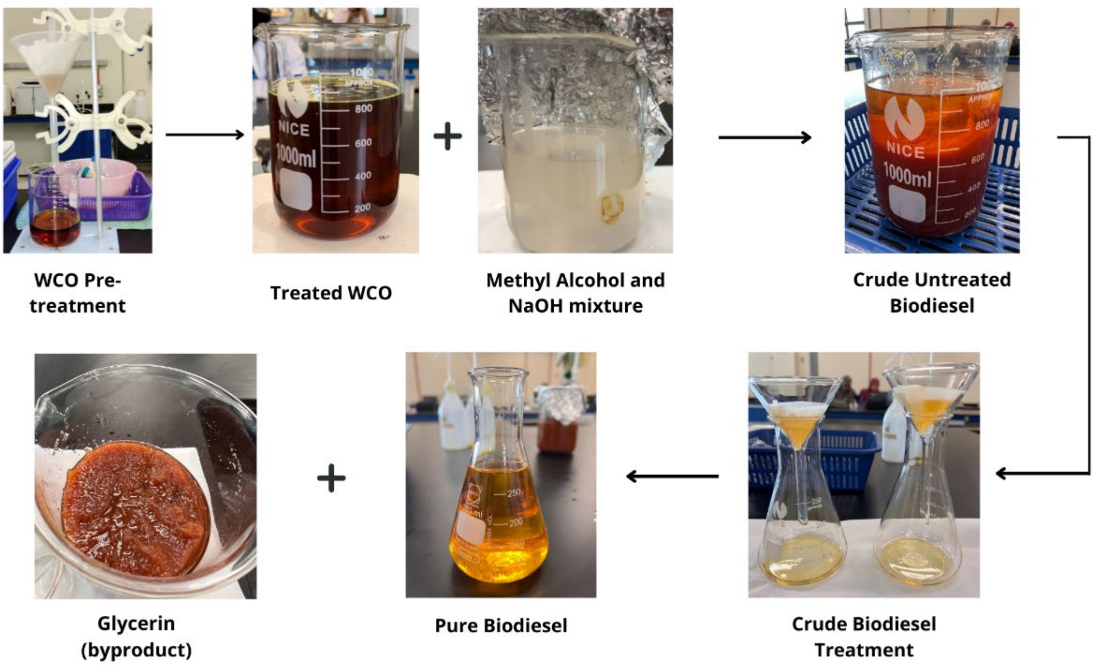

Figure 1: General process flow chart of biodiesel production from WCO

2.1 Pre-treatment of WCO

WCO was left for 24 hours inside a container to allow large particles to sediment at the bottom. This will facilitate the filtration process. After that, the WCO was filtered through a filter paper to remove any smaller suspended impurities. Then, the filtered WCO was then heated at 110ºC with constant stirring for 30 minutes to evaporate any remaining water. The WCO was left to cool at room temperature.

2.2 Methyl alcohol and catalyst preparation

Sodium hydroxide (NaOH) was used as the catalyst for this research because it is a strong alkali. 12 g of NaOH was measured using an analytical balance. The NaOH pellets were then grinded into powdered form using a mortar and pestle to increase surface area for higher rate of solubility. 150 mL of methyl alcohol was placed on a hot plate and stirrer. The NaOH was added into the methyl alcohol with low heat and constant stirring until all NaOH has been dissolved. The mixture was left to cool to room temperature.

2.3 Transesterification

The filtered WCO was heated to 55ºC on a hot plate with constant stirring. The methyl alcohol and NaOH mixture was added into the WCO, and the heat was immediately turned off with continued stirring for 45 minutes. After that, the mixture was left at room temperature for 24 hours. This allowed all the WCO to react with the methyl alcohol and simultaneously allowing the glycerin to sediment at the bottom for ease of separation.

2.4 Treatment of crude biodiesel

Biodiesel was filtered through a filter paper to remove suspended glycerin. After that, the biodiesel was washed using distilled water to remove dissolved glycerin. The washed biodiesel was left for 24 hours. This allowed the glycerin to sediment at the bottom. This process was repeated five more times until a clear and pure biodiesel was obtained. The pure biodiesel was stored in a closed container as to prevent external contamination.

2.5 Density calculation

The density of biodiesel converted from WCO was calculated to determine whether if it has the same density as biodiesel that are produced from other sources. The density of biodiesel was measured using the standard method using a capillary relative density bottle of 50 mL in volume. The density of biodiesel was calculated using the following equation:

$$\text{Density} = \frac{W_3 - W_1}{W_2 - W_1} \times \rho H_2O \qquad \textbf{Eq. 1}$$

where W_1 is the weight of the empty bottle, W_2 is the weight of the bottle filled with distilled water, W_3 is the weight of the bottle filled with biodiesel and ρH_2O is the density of water.

2.6 Viscosity calculation

The viscosity of biodiesel converted from WCO was calculated to determine whether if it has the same viscosity as biodiesel that are produced from other sources. The method used to measure the dynamic viscosity of the biodiesel converted from WCO is similar to the mechanism of a falling sphere viscometer using the following equation:

$$\text{Dynamic Viscosity} = \frac{[2(\rho_s - \rho_I)ga^2]}{9v} \qquad \textbf{Eq. 2}$$

where ρ_s is the density of the sphere, ρ_l is the density of the biodiesel, g is the acceleration due to gravity that is fixed at 9.8 m/s^2, a is the radius of the sphere and v is the velocity of the sphere. The dynamic viscosity was then converted to kinematic viscosity using the following equation:

$$\text{Kinematic Viscosity} = \frac{\text{Dynamic Viscosity}}{\text{Density of Biodiesel}} \qquad \textbf{Eq. 3}$$

2.8 Fourier Transform Infrared (FTIR) spectroscopy characterization of biodiesel

The functional groups present in the biodiesel produced from WCO was characterized by using an Agilent Technologies Cary 630 FTIR with wavelengths ranging from 600 – 4000 cm^{-1}. FTIR spectroscopy was performed to compare the spectrum produced by the biodiesel converted from WCO and the spectrum of biodiesel that are produced from other sources.

3. Results and Discussions

The chemical property of WCO is analyzed using FTIR to identify the functional group of WCO. In addition, the physical properties of WCO are analyzed based on its density and viscosity of WCO.

3.1 FTIR analysis of biodiesel

The functional group composition of biodiesel produced from WCO at spectrum regions 600-4000 cm^{-1} is shown in **Figure 2**. The stretching vibration of C=O at 1741 cm^{-1} indicates the presence of the ester group. The stretching vibration of C-H at 2922 cm^{-1} indicates the presence of $-CH_3$, a molecular structure present in methyl esters. The stretching vibration of C-O shown at 1168 cm^{-1} indicates the presence of C-O, also a molecular structure present in methyl esters. From this FTIR spectrum result, it is clear that methyl ester is present in the biodiesel converted from WCO, therefore acts as proof that biodiesel has been successfully produced.

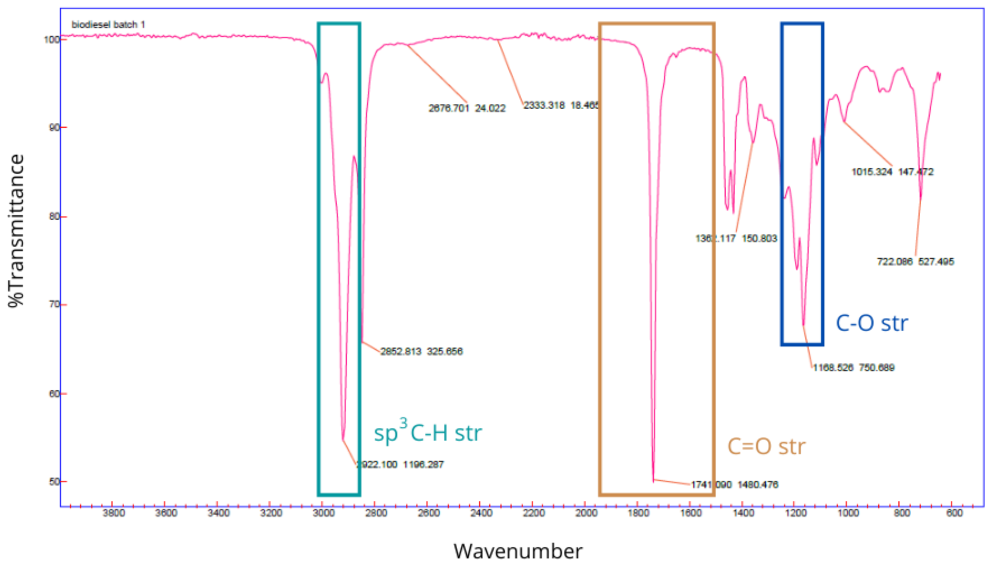

Figure 2: FTIR spectrum of biodiesel produced from WCO

The FTIR spectrum for biodiesel converted from WCO was compared to the FTIR spectrum of biodiesel produced from jatropha oil as shown in **Figure 3** [4]. At around 1730-1750 cm^{-1}, we can clearly see a stretching vibration of the C=O which indicates the presence of the ester group. This stretching vibration is also present in the FTIR spectrum for biodiesel converted from WCO at 1741 cm^{-1}. Apart from that, at around 1100-1150 cm^{-1}, the stretching vibration for C-O is present, which is a molecular structure present in methyl esters. This stretching vibration is also present in the FTIR spectrum for biodiesel produced from WCO where it is present at 1168 cm^{-1}. This shows that the biodiesel produced from WCO has an almost similar FTIR spectra, indicating that biodiesel is successfully converted from WCO.

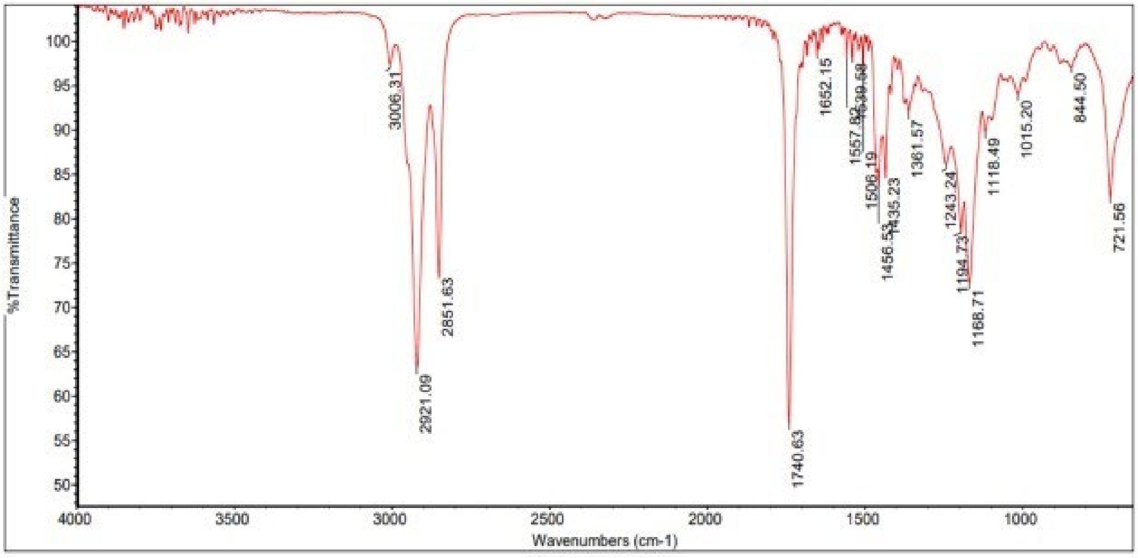

Figure 3: FTIR spectrum of biodiesel produced from jatropha oil [4]

3.2 Density of biodiesel

Density refers to the amount of mass per unit volume of a substance. Because injection systems, pumps, and injectors must deliver a precise amount of fuel to ensure proper combustion, density is a crucial fuel property. Density of fuel is the main criteria that affects the amount of fuel injected into engines [5]. The density of biodiesel produced from WCO has been calculated to be 0.85 kg/m^3.

Table 1 shows the comparison in terms of density between biodiesel produced from oils of sunflower, soybean, rapeseed, palm, linseed and jatropha [6]. The result shows that the density of biodiesel converted from WCO was almost identical to the density of biodiesel that are produced from other sources. This was due to the fact that the biodiesel converted from WCO contains methyl ester, the same ester that can be found in the other biodiesels.

Table 1: Density comparison of biodiesel produced from different sources [6]

Source	**Density (kg/m^3)**
Sunflower oil	0.86
Soybean oil	0.89
Rapeseed oil	0.88
Palm oil	0.88
Linseed oil	0.89
Jatropha oil	0.89

3.3 Viscosity of biodiesel

Viscosity is a term used to describe the amount of internal friction present in a fluid and is calculated as the force per unit area that opposes uniform flow. The viscosity of biodiesel is one of its most crucial characteristics because it has an impact on the fuel injection system, particularly in cold climates where viscosity rises with temperature [7]. The kinematic viscosity of biodiesel produced from WCO was calculated to be 5.76 mm^2/s.

Table 2 shows the comparison in terms of kinematic viscosity between biodiesel produced from oils of sunflower, soybean, rapeseed, palm, linseed and jatropha [6]. The result shows that the kinematic viscosity of biodiesel converted from WCO was the highest compared to biodiesel produced from other sources. The high value of kinematic viscosity was caused by the high fatty acid composition. When the concentration of fatty acids increases, the kinematic viscosity of the biodiesel also increases in value [8].

Table 2: Kinematic viscosity comparison of biodiesel produced from different sources [6]

Source	Kinematic Viscosity (mm^2/s)
Sunflower oil	4.40
Soybean oil	4.02
Rapeseed oil	5.65
Palm oil	3.85
Linseed oil	4.01
Jatropha oil	5.15

4. Conclusion

Using WCO as a source to produce biodiesel is beneficial to the environment. Not only will it reduce carbon emissions, but it will also reduce pollution caused by improper disposal of WCO into the environment. Results have shown that biodiesel produced from WCO has almost similar physical properties to biodiesel produced from other sources in terms of density and viscosity which are 0.85 kg/m^3 and 5.76 mm^2/s respectively, making it at par with biodiesel currently in the market. Analysis using the FTIR spectrum indicates that methyl esters are present in the biodiesel produced from WCO, a key component in biodiesel. Comparing the FTIR spectrum of biodiesel produced from WCO with the FTIR spectrum for biodiesel converted from soybean oil shows similar spectra, indicating the presence of similar functional groups which are C-O, C=O, and C-H. Glycerin, a byproduct produced when producing biodiesel from WCO has potential to be used in soap production, cosmetics, and pharmaceuticals. It is suggested that further research is put into glycerin conversion into useable products so that all components of WCO is not wasted.

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References

[1] S. K. Bhatia, R. K. Bhatia & Y. H. Yang. (2017). “An Overview of Microdiesel – A Sustainable Future Source of Energy.” *Renewable and Sustainable Energy Reviews*. **79** (May 2017). 1078-1090.

[2] Cholapandian, K., Gurunathan, B. & Rajendran, N. (2021). “Investigation of CaO Nanocatalyst Synthesized from Acalypha Indica Leaves and its Application in Biodiesel Production using Waste Cooking Oil.” *Fuel*. **312** (September 2021). 122958.

[3] Fangfang, F., Alagumalai, A. & Mahian, O. (2021). “Sustainable Biodiesel Production from Waste Cooking Oil: ANN Modeling and Environmental Factor Assessment.” *Sustainable Energy Technologies and Assessments*. **46** (May 2021). 101265.

[4] Amesho, K. T. T., Lin, Y., Chen, C., Cheng, P. & Shangdiar, S. (2021). “Kinetic Studies of Sustainable Biodiesel Synthesis from Jatropha curcas Oil by Exploiting Bio-waste Derived from CaO-based Heteregenous Catalyst via Microwave Heating System as a Green Chemistry Technique.” *Fuel*. **323** (2022). 123876.

[5] Pratas, M. J., Freitas, S. V. D., Oliveira, M. D., Monteiro, S. C., Lima, A. C. & Coutinho, J. A. P. (2011). "Biodiesel Density: Experimental Measurements and Prediction Models." *Energy and Fuels*. **25** (5). 2333-2340.

[6] Krishnasamy, A. & Bukkarapu, K. R. (2021). "A Comprehensive Review of Biodiesel Property Prediction Models for Combustion Model Studies." *Fuel*. **302** (July 2021). 121085.

[7] Kassem, Y & Çamur, H. (2016). "A Laboratory Study of the Effects of Wide Range Temperature on the Properties of Biodiesel Produced from Various Waste Vegetable Oils." *Waste and Mass Valorization*. **8** (6). 1995-2007.

[8] Roy, M. M., Wang, W. & Bujold, J. (2013). "Biodiesel Production and Comparison of Emissions of a DI Diesel Engine Fuelled by Biodiesel-Diesel and Canola Oil-Diesel Blends at High Idling Operations." *Applied Energy*. **106** (2013). 198-208.