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Determination of the Viscosity of Trans-esterified Garlic Oil

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Abstract

The use of renewable energy sources, such as biodiesel, has emerged as a promising solution to mitigate the challenges associated with fossil fuel consumption. Biodiesel can be synthesized through various methodologies, including transesterification, microemulsion, and pyrolysis. In this study, we focused on investigating the viscosity of transesterified garlic oil, a potential biodiesel feedstock. Firstly, crude Jatropha oil underwent purification and transesterification processes. Subsequently, Fourier Transform Infrared (FTIR) analysis was conducted to assess the presence of esters (biodiesel) in the transesterified samples. Additionally, the viscosities of the samples were measured across a temperature range from 20°C to 70°C, at intervals of 10°C, utilizing a Brookfield viscometer. The FTIR results confirmed the presence of esters in the transesterified samples, indicating successful biodiesel production. Furthermore, our viscosity measurements revealed a decrease in viscosity with increasing temperature, suggesting the feasibility of utilizing garlic oil as a biodiesel feedstock via the transesterification process.

Keywords: *FTIR , Garlic oil, Purification, Transesterification, Viscosity.*

1. Introduction

Energy is a fundamental requirement for economic development in any country. With the growth of human population and industrialization, there has been a simultaneous increase in energy demands. Traditional sources of energy such as petroleum, natural gas, and coal derived from fossil fuels have long been relied upon (Musa et al., 2022). However, the adverse global environmental impacts associated with the use of fossil fuels raise concerns about their sustainability for fostering economic growth. To address this challenge, there is a growing interest in renewable sources of energy (Banwal & Sharma, 2005). Biodiesel emerges as a viable alternative, offering several advantages over fossil diesel, including more environmentally friendly production processes, biodegradability, non-toxicity, reduced greenhouse gas emissions, and absence of sulfur and aromatics (Kanwal et al., 2022; Jamo et al., 2023).

Biodiesel, derived from the chemical conversion of animal fats or vegetable oils, is gaining prominence (Nigam & Singh, 2011; Ismail et al., 2022). It can be produced from a variety of renewable resources, including both edible vegetable oils (such as peanut, garlic, clove, sesame, and palm kernel oils) and non-edible vegetable oils (such as Jatropha, castor, calabash, and neem oils), as well as animal fats and waste cooking oil (Gebremanian & Marchetti, 2018). While animal fats, with their high saturated fatty acid content, pose challenges in processing due to their solid state at room temperature, vegetable oils are more favorable and have garnered greater attention (Knoth, 2010; Batani et al., 2017). Therefore, vegetable oils are preferred for biodiesel production due to their easier processing and lower associated costs compared to animal fats (Ismail et al., 2022). Garlic, scientifically known as Allium sativum, belongs to the onion family and is widely used in cuisines around the world. Cultivated primarily in tropical regions, garlic not only adds flavor to dishes with its pungent taste but also offers numerous health and medicinal benefits. Garlic oil contains volatile sulfur compounds such as diallyl disulfide, which make up about 60% of the oil. Typically obtained through steam distillation, garlic oil has a strong and somewhat unpleasant odor and appears brownish-yellow in color (Satyal et al., 2017).

Transesterification is a chemical process in which fats or oils react with alcohol to form esters and glycerol. A catalyst is used to enhance the reaction rate and yield. Since the reaction is reversible, excess alcohol is often employed to shift the equilibrium towards the product side (Muhammad et al., 2023). Viscosity refers to the resistance of a liquid to flow and is determined by measuring the time taken for a specific volume of oil to pass through an orifice of a defined size. Kinematic viscosity is a crucial property of biodiesel as it influences the operational performance of fuel injection equipment, especially at lower temperatures. Research has shown that the viscosity of oil methyl esters decreases significantly following the transesterification process used in biodiesel production (Jamo et al., 2023).

Despite the importance of viscosity in biodiesel production, there is a lack of literature regarding the viscosity of transesterified garlic oil. Therefore, the aim of this paper is to determine the viscosity of biodiesel produced from garlic oil.

2. Material and Methods

2.1 Chemicals and Equipment

The materials and reagents utilized in this study include crude garlic oil (Linnaeus), silicon reagent, acetone, 8% sodium hydroxide (NaOH), activated carbon, distilled water and 64% citric acid ($C_6H_8O_7$, purity: 99.7%). Meanwhile, the equipment employed comprises a magnetic stirrer with a thermostatically controlled rotary hot plate (IKA C-MAG HS10), Brookfield Digital viscometer model (Brookfield, RVDV-I), thermometer, measuring cylinder, Digital weight balance (AND model GT2000 EC), beaker, 24 cm filter paper, funnel, Digital stopwatch, sampling bottles, and spatula.

2.2 Methodology

The methodologies employed during this research are;. Sample purification, Transesterification and sample measurement.

2.2.1 Garlic oil Purification

200 ml of garlic oil was measured using a measuring cylinder and heated to 70°C using a hot magnetic stirrer with a built-in thermometer. Subsequently, 1.5 ml of citric acid was introduced into the heated oil sample and the mixture was continuously heated and stirred for 15 minutes at 70°C. Additionally, 4 ml of 8% NaOH solution (prepared by dissolving 8g NaOH in 100 ml of distilled water) was added to the oil and continuously heated and stirred for another 15 minutes at 70°C. The resulting mixture was then transferred to a vacuum oven and heated at 85°C for 30 minutes. Afterward, it was returned to the hot magnetic stirrer, and 2g of silicon reagent was added while heating and stirring for 30 minutes. The temperature was then raised to 85°C, and 4g of activated carbon was added to each 100 ml of the oil sample, followed by heating and stirring for an additional 30 minutes. Finally, the mixture was separated using filter paper, following the analytical procedure detailed by Nura et al. (2023).

2.2.2 Garlic Oil Transesterification

60 grams of garlic oil were carefully measured and placed into a 250 ml conical flask. The mixture was then heated and stirred until it reached a temperature range of 60-65°C on a hot magnetic stirrer plate. Meanwhile, 0.6 grams of NaOH were dissolved in 21 ml of methanol and added to the heated mixture, which was allowed to continue heating for 60 minutes with continuous stirring on the hot magnetic plate. Following this uniform stirring and heating

process for 60 minutes, while maintaining a temperature of 65°C, the mixture was transferred into a separating funnel via a glass funnel. Subsequently, the mixture was left to cool for approximately 40 minutes. Upon cooling, it was observed to separate into two distinct liquid layers, with the upper layer identified as biodiesel and the lower layer as triglyceride fatty acid. The biodiesel was then carefully separated from its byproduct using standard procedures, as described by Ismail et al. (2022).

2.2.3 Fourier Transform Infrared (FTIR) Spectroscopy Analysis

FTIR analysis was conducted to identify and demonstrate the presence of key compounds, specifically methyl esters, in the samples. During the analysis, the sample was transformed into a thin film and inserted between two potassium bromide discs crafted from single crystals. A drop of the liquid sample was placed on one disc, and another disc was then positioned on top, causing the sample to spread into a thin film. The FTIR machine's radiation source emitted radiation that traversed through the sample, the interferometer, and eventually reached the detector. The detected signal was subsequently amplified and converted into a digital signal by the amplifier and analog-to-digital converter, respectively. Finally, the digital signal underwent Fourier transform on a computer for analysis, as detailed by Ismail et al. (2022).

2.2.4 Measurement of Viscosity

Viscosity measurements were conducted using a Brookfield viscometer model DV-II+PRO (S/N 621-216) equipped with a spindle size of 2 and an operational speed range of 50 rpm. The crude garlic oil was placed into a beaker, and the viscometer was initiated with a specified angular speed. The viscometer then determined and displayed the viscosity of the crude garlic oil, which was subsequently recorded. This procedure was repeated for both the purified and transesterified garlic oils to measure their respective viscosities, as outlined by Jamo et al. (2023).

3. Results and Discussion

3.1 FTIR Analysis

Figure 1 displays the FTIR spectrum, illustrating transmittance (%) plotted against wave number (cm^{-1}), representing the light absorption patterns of specific molecules within the transesterified garlic oil. Bonds within the range of 650 to 1400 cm^{-1} denote C-O bonds, while those between 1500 to 1800 cm^{-1} signify C=O bonds. The region spanning 2700 to 3000 cm^{-1} indicates C-H stretching, and from 3000 to 3700 cm^{-1} depicts OH bonds. The presence of ester or ether groups in the sample is indicated by the C-O and C=O peaks, consistent with findings outlined by Ismail et al. (2022). Accordingly, the ester peak at 1750 cm^{-1} aligns with results reported by Muhammad et al. (2023).

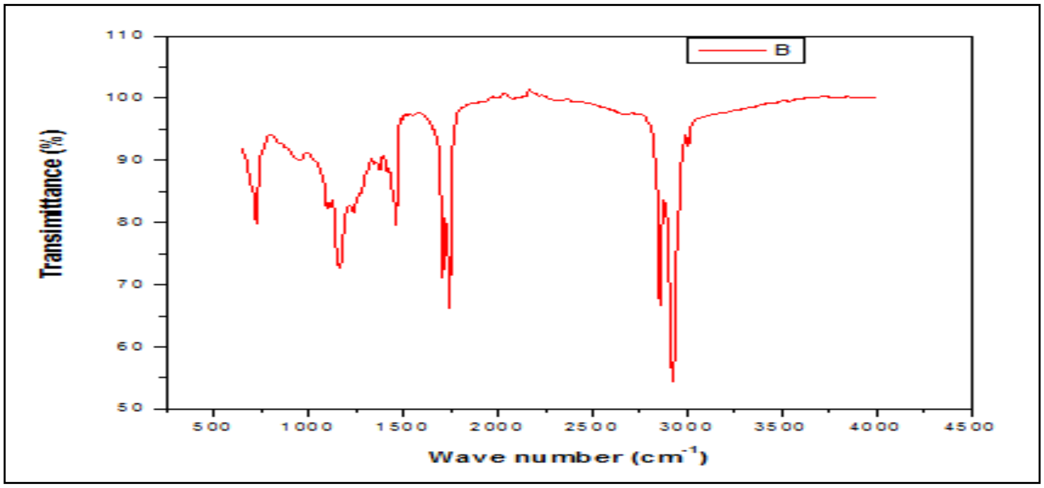

Figure 1: FTIR Spectra of Transesterified Garlic oil

3.2 Viscosities of the Samples

Table 1 presents the viscosity values of crude, purified, and transesterified neem oil in mPa·s. It is evident from Table 1 that the viscosity of crude garlic oil decreases from 84.2 mPa·s at 20°C to 33.2 mPa·s at 70°C. Similarly, purification results in a decrease from 75.2 mPa·s at 20°C to 24.5 mPa·s at 70°C, and the transesterified oil exhibits a decrease from 66.3 mPa·s at 20°C to 15.4 mPa·s at 70°C. This reduction in viscosity can be attributed to the temperature increase and the removal of residues and glycerol from the crude garlic oil. The transesterified viscosities listed in Table 1 adhere to ASTM standards and align closely with results reported by Raja et al. (2011), Musa et al. (2022), and Jamo et al. (2023).

Table 1:Viscosity of crude, purified, and transesterified Garlic oil.

	Viscosity (mPa·s)		
Temp. (^{0}C)	**Crude Garlic Oil**	**Purified Garlic Oil**	**Transesterified Garlic Oil**
20	84.2	75.2	66.3
30	70.3	62.2	55.4
40	68.8	55.3	43.6
50	53.2	44.2	35.4
60	45.3	33.3	25.5
70	33.2	24.5	15.4

Figure 2 depicts a graphical representation of the viscosity values (mPa·s) of crude, purified, and transesterified neem oil against temperature (°C), as outlined in Table 1. It is evident that as the temperature increases, the viscosity decreases. The decrease can also be attributed to the purification and transesterification processes undergone by the oil.

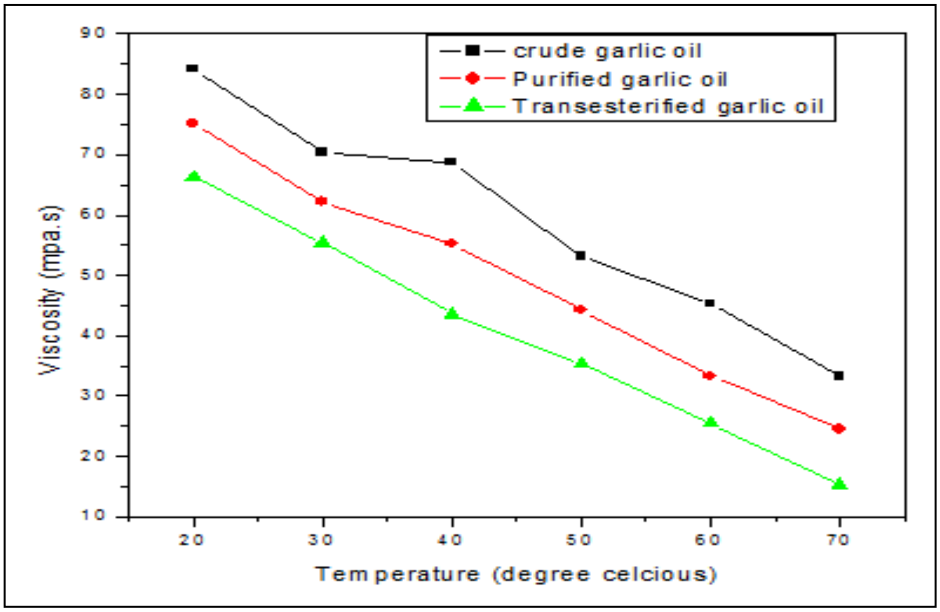

Figure 2: Variation of viscosity against temperature

4. Conclusion

In conclusion, the FTIR spectral analysis confirms the production of biodiesel through the trans-esterification reaction. The dynamic viscosities of the samples (crude, purified, and transesterified neem oil) were measured at various temperatures, revealing a consistent decrease as temperature increased. Additionally, the viscosity of crude garlic oil decreased from 84.2 mPa·s to 33.2 mPa·s, while for purified oil, it decreased from 75.2 mPa·s to 24.5 mPa·s. Similarly, for transesterified oil, viscosity decreased from 66.3 mPa·s to 15.4 mPa·s over the temperature range of 20°C to 70°C.

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