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EFFECTS OF ADDITION OF BANANA PEELS ON THE RHEOLOGICAL PROPERTIES OF TRANSESTERIFIED CALABASH OIL

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ABSTRACT
Biodiesel has emerged as a viable alternative to fossil diesel, offering a renewable energy source. However, most biodiesel produced through transesterification has a viscosity exceeding the diesel limit, leading to ignition delay and engine clutching. Research suggests that powdered additives can mitigate this issue. This study investigates the effect of banana peel additives on the rheological properties of transesterified calabash oil. The morphology and elemental composition of banana peels were analyzed using Scanning Electron Microscopy (SEM) and X-ray Fluorescence (XRF). The results show that adding banana peels reduces the viscosity of the biodiesel, with a significant variation observed at 0.5wt% additive concentration. These findings indicate that banana peels can be used as a biodiesel additive to improve the rheological properties of transesterified calabash oil."

Keywords: Banana peels, Calabash oil, Rheology, Temperature, Viscosity

INTRODUCTION

The main force behind socioeconomic advancements of any nation is energy which is sorely generated from fossil fuels (Ismail *et al.,* 2022). The use of fossils fuels in energy generation leads to the release of greenhouse gases into the atmosphere, which contributes significantly to environmental pollution and global warming (Nath *et al.,* 2019). Environmental problems, rising of fuel prices, and the slow depletion of fossil fuel reserves all have affected the economic growth and environmental stability of many nations. This has raised a question on the alternative fuels (Brahma, *et al*., 2022). Although researchers are improving ways to generate energy from green and renewable resources such the sun, wind, water, ocean, and tides, none of them are meeting the requirements of replacing traditional fossil fuels. Therefore, in order to survive in the current deteriorating circumstances, a feasible renewable green fuel is required. Biofuels such as biogas, bioethanol and biodiesel are emerging as remarkable candidates to meet the future energy demands in replacing the fossil fuels (Fadara *et al.,* 2021). Since the last two decades, biodiesel produced from transesterification process has been competing itself as a potential substitute to fossil fuel due to its well-comparable properties with petro diesel such as viscosity, density, volatility among others (Manigandam *et al.,* 2020; Mahesha *et al.,* 2022).

The U.S. Department of Energy defines biodiesel as renewable, biodegradable fuel manufactured from vegetable oils, animal fats of recycled restaurant grease" (Muhammad *et al.,* 2023). Vegetable edible oils (pea nut, clove, sesame, palm cannel etc.) and non-edible vegetable oils (Jatropha, castor, calabash, neam etc.) are more favorable and draw higher attention than animal fats. This is due to the facts that animal fats with high saturated fatty acids which normally exist in a solid form at room temperature cause problems in the biodiesel production process (Zakari *et al.,* 2024). Biodiesel production depends mainly on edible vegetable oils due to their high potentiality, but its frequent utilization may prompt some undesirable impacts such as starvation and rise in food prices in developing countries. Therefore, non-edible plant oils such as calabash oil turn out to be the optional feedstock for biodiesel production (Jamo *et al.,* 2023).

Calabash seeds, scientifically known as Lagenaria siceraria, originate from a trailing plant found in various regions, particularly in parts of Asia and Africa (Elendu, *et al.*, 2024). The seed comprises of about 38–40% oil.

Different solid materials such as fly ash, banana peels etc. were used as biodiesel additive in order to improved its quality (Zakari *et al.,* 2024). Banana peel (*Musa sapient*) as biodiesel additive contains minerals composition of phosphorus, iron, calcium, magnesium, sodium, zinc, copper, potassium, and manganese (Hikal *et al.,* 2022). (Betiku *et al.,* 2016) reported that the mineral composition of peels ash sample as K (51.34%), Na (37.20%), Mg (7.60%), Ca (31.20%), Cu (20.10%), Fe (1.30%), Zn (2.90%) and Pb (2.80%).

Viscosity is the resistance of liquid to flow which is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size. There are two types of viscosity which include kinematic viscosity (cSt) and dynamic viscosity (mm^2/s or mPa.s) (Jamo *et al.,* 2023). Viscosity is the most important rheological properties of biodiesel since it affects the operational performance of fuel injection equipment, particularly at low temperatures. It has been shown that the viscosity oil methyl esters decrease sharply after transesterification of the oil (Zakari *et al.,* 2024). In a research conducted by Raja *et al.,* (2011) found out the viscosity of Jatropha biodiesel decreases from 57 to 4.73cSt. Ali *et al.,*(2013) found the viscosity of neem oil biodiesel as 5.9cSt and similarly Djibri *et al.,* (2015) found the viscosity of neem oil to be 35.8mm^2/s at 40^0C. Musa *et al.,* (2022) found that the viscosity of transesterified neem oil decreases from 96mpa.s at the temperature of 10°C to 24mpa.s at the temperature of 100°C. Equally Jamo *et al.,* (2023) has found the viscosity of jatropha oil to decrease after transesterification from 57.3cSt to 4.6cSt

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The high values of viscosity associated with the biodiesel produced give rise to poor fuel atomization, incomplete combustion, and carbon deposit on the injectors (Ismail *et al.,* 2022). These problems give rise to operational problems like difficulty in engine starting, unreliable ignition and deterioration in thermal efficiency (Gashaw and Lakachew, 2014). Different solid materials (fly ash, calcium oxide, silicon oxide, eggshell, crab shell) was used as additive in order to improve the quality of biodiesel which eventually reduced the amount of viscosity presence on the biodiesel (Ismail *et al.,* 2022). But the use of banana Peels as additive on transesterified calabash oil was not been reported in the literature. Therefore the aim of the presence study is to evaluate the effects of banana peels as additive on the rheological properties of transesterified calabash oil.

MATERIALS AND METHODS

Chemicals and Equipment

The chemicals, reagent and materials used in carrying out this research were; crude neem oil, sodium hydroxide (NaOH), banana peels, methanol, 64 % citric acid (C 6H8O7, purity: 99.7%), Silicon reagent, activated carbon, acetone and distilled water (H_2O).

The equipment used in carrying out this research were: magnetic stirrer with thermostatically controlled rotary hot plate (IKA C-MAG HS10), thermometer, measuring cylinder, Digital weight balance (AND model GT2000 EC), beakers, conical flask, 24 cm filter paper, funnel, Digital stop watch, digital viscometer, sampling bottles, spatula, XRF machine and SEM machine.

Methodology

SEM Characterization of Banana Peels

The Scanning Electron Microscope (SEM) characterization of banana peels was done using multipurpose SEM PHENOM PRO X MVE01570775. One gram of banana peels was scanned with a focused electron beam. The electrons interact with banana peels atoms which produces various signals that revels its surface morphology. The electron beam is scanned in a scattered pattern, and the position of the beam is combined with the intensity of the detected signal which finally produces the image of the banana peels (Zakari *et al.,* 2024).

XRF Characterization of Banana Peels

X-ray fluoroscopy characterization of banana peels was done using ARL QUANT'X EDXRF Analyzer (S/N 9952120) where by the incoming X-rays from an XRF machine knock the electron of 1g of banana peels atom out of the inner orbital. This results in the excitation of the atom and the production of high-energy radiation (photons, protons, electrons, etc.). The next process involves the detection and integration of characterized emitted lines to give varying levels of intensity. Finally, the detected line intensities are converted to elemental concentrations which is then displaced on the monitor (Ismail *et al.,* 2022).

Purification of Calabash Oil

The crude calabash oil was purified through a multi-step process. Firstly, 200ml of oil was heated using a hot magnet stirrer, and 0.5g of citric acid dissolved in 1.5ml of distilled water was added. The mixture was heated and stirred for 15 minutes. Next, 4ml of 8% NaOH solution was added, and the mixture was heated and stirred for another 15 minutes. The mixture was then transferred to a vacuum oven for 30 minutes. Afterward, it was heated and stirred with 2g of silicone reagent for 30 minutes. Finally, 4g of activated carbon was added to each 100ml of oil, and the mixture was heated and stirred for 30 minutes before being separated using a separating funnel (Zakari *et al.,* 2024).

Transesterification of Calabash Oil

A 60g of calabash oil was measured into a 250ml conical flask and heated to 60-65°C on a hot magnetic stirrer. 0.6g of NaOH was dissolved in 21ml of methanol and added to the oil mixture. The mixture was stirred and heated for 60 minutes at 65°C. After cooling for 40 minutes, the mixture separated into two distinct layers in the separating funnel: the upper layer was biodiesel, while the lower layer was triglyceride fatty acid (Ismail *et al.,* 2022).

Nano Fluid Preparation Using Banana Peels

Banana peels powder was added to 10g of transesterified calabash oil at varying concentrations (0.1-1.0wt%) at the interval of 0.1wt% and thoroughly mixed for 2-3 hours using a magnetic stirrer. The resulting mixtures were then analyzed (Nura *et al.,* 2023).

Infrared Spectral Analysis

Fourier Transform Infrared (FTIR) spectroscopy was performed using a SHIMADZU FTIR-8400S machine to identify the functional groups present in the sample. A thin film of the sample was prepared by placing a drop between two potassium bromide discs. The sample was then exposed to infrared radiation, which passed through the sample and was detected. The detected signal was amplified, digitized, and transferred to a computer, where a Fourier transform was applied to analyze the spectral data (Durumin-Iya *et al.,* 2024).

Measurement of Viscosity

Viscosity was measured using Brookfield viscometer DV-II+PRO (S/N 621-216) with an operational speed range of 50 rpm with spindle size of 2. The crude calabash oil was poured into a beaker then the viscometer was started and angular speed was selected on it. The Viscometer revel the viscosity of the crude calabash oil which has been read and recorded. The same procedure has been applied to the purified, transesterified and transesterified calabash oil with the addition of banana peels concentration of 0.1 to 1.0wt% at the interval of 0.1wt% (Nura *et al.,* 2023).

RESULTS AND DISCUSSIONS

SEM of Banana Peels

Figures 1shows the scanning electron microscopic analysis (SEM) of the banana peels at 1000x magnification (800μm and 15kV) which reveals the presence of mountainous, irregular and cloudy structure. This was similar to the result obtained by (Banković-Ilić, *et al*., 2020).

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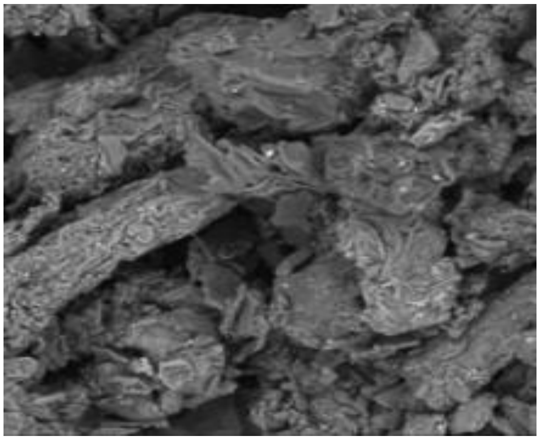

Figure 1: SEM of banana peel at 1000x magnifications.

XRF of Banana Peels

Table 1 shows the XRF of banana peels in terms of elemental concentration.

Table 1: Percentage concentration of element.

S/NO.	Elements	Symbol	Percentage Concentration (%)
1	Oxygen	**O**	36.2
2	Calcium	**Ca**	31.2
3	Potassium	**K**	3.62
4	Zinc	**Zn**	2.90
5	Iron	**Fe**	1.3
6	Chlorine	**Cl**	0.414
7	Phosphorus	**P**	0.174
8	Sodium	**Na**	0.037
9	Sulphur	**S**	0.03
10	Magnesium	**Mg**	0.035
11	Robium	**Rb**	0.009
12	Boron	**Br**	0.002
13	Cupper	**Cu**	0.001

It can be seen from table 4.1 above, **O** was 36.2%, **Ca** was 31.2%, **K** was 3.627%, **Zn** was 2.90%, **Fe** was 1.3%, **P** was 0.174%, **Cl** was 0.414%, **Na** was 0.037%, **S** was 0.037%, **Mg** was 0.035%, **Rb** was 0.009%, **Br** was 0.002% and **Cu** was 0.001%. It can be seen that **O**, **Ca,** and **K** have the highest elemental percentage concentration on the banana peels. This indicates that the banana peels can be used as biodiesel additive without any environmental problem. This was similar results obtained by (Meriatna, *et al*., 2023).

FT-IR Spectra of the Transesterified Calabash Oil

The FTIR spectrum revealed specific bond assignments: C-O bonds (650-1400 cm^{-1}), C=O bonds (1500-1800 cm^{-1}), C-H stretching (2700-3000 cm^{-1}), and OH bonds (3000-3700 cm^{-1}). The presence of C-O and C=O bonds indicates the existence of ester or ether groups in the sample (Ismail *et al.,* 2022).

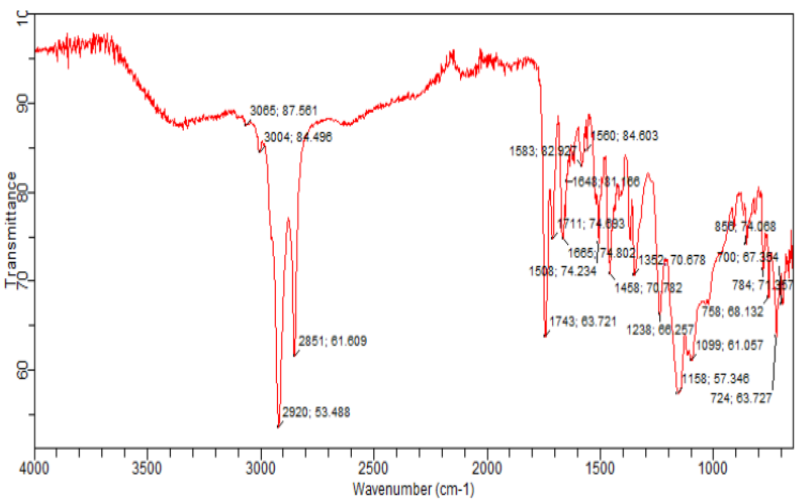

Figure 2: FT-IR Spectra of trans-esterified calabash oil.

Figure 1 illustrates the FT-IR of transesterified calabash oil which shows the spectrum plotted for transmittance (%) against the wave number (cm^{-1}) based on the amount of light absorbed by specific molecules present in the transesterified calabash oil. It indicated that the ester (biodiesel) was achieved at 724, 1158 and 1743 peaks. Similar results were obtained by Meriatna *et al.,* (2023).

Viscosity of the Samples

Figure 3 shows the viscosity of crude, purified, and transesterified calabash oil in (mpa.s) against temperature in degree Celsius.

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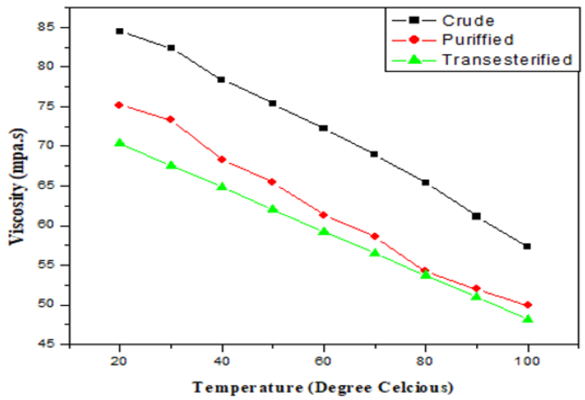

Figure 3: Viscosity of crude, purified and trans-esterified calabash oil against temperature.

It can be observed from Figure 3 that crude calabash oil has higher viscosity than purified oil, which is, in turn, more viscous than trans-esterified oil. This variation is as a result of the reduction in the amount of impurities present on the crude oil after purification. The same trend has been observed as the oil is been transesterified which is as a result of the reaction between the methanol and the oil (Musa *et al.,* 2022; Durumin-Iya *et al*., 2024).
It can also be seen from Figure 3 that as the temperature rises from 20°C to 100°C, the viscosity of crude oil drops from 84.5mpa.s to 57.34mpa.s. Similarly, for purified oil, its viscosity decreases as the temperature increases, going from 72.6mpa.s to 23.7mpa.s. The same trend is seen with trans-esterified oil, whose viscosity falls from 75.14mpa.s at 20°C to 49.88mpa.s at 100°C. This is similar to the result obtain by Jamo *et al.,* (2023) and Zakari *et al.,* (2024) Figure 5 revels the viscosity of trans-esterified calabash oil with the addition of banana peels in (mpa.s) against temperature in degree Celsius.

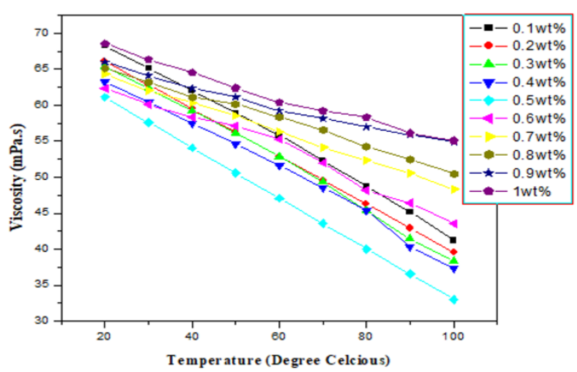

Figure 4: Viscosity of trans-esterified calabash oil with the addition of banana peels against temperature.

Figure 4 shows that the viscosity decreases with rise in temperature from 20^0 to 100^0 for all the samples (0.1 to 1wt%) at irregular intervals with the exception of 0.5wt%. This is as a result of the interaction between the transesterified calabash oil and the banana peels powder. Similar pattern was observed by Jamo *et al.,* (2023). It can equally deduced from Figure 4 that the viscosity decreases with increase in the concentration of banana peels until it reaches 0.5wt% then it rises. This was attributed due the over addition of the additive which tend to make the oil more viscous than those below 0.5wt%. This shows that 0.5wt% of banana peels tend to be the best among all the samples. In a research conducted by Durumin- Iya *et al.,* (2024) similar results were obtained.

Conclusion
This paper evaluate the effects of the addition of banana peels on the rheology of transesterified calabash oil. The viscosity of the samples decreases as the temperature increases and with the addition of banana peels, but at 0.5wt% shows variation at standard interval for the change in temperature. This indicate a potential biodiesel additive behaviour of banana peels at 0.5wt% on transesterified calabash oil for all applications. Therefore it can be concluded that banana peels can be used as biodiesel additive on calabash oil. It can be suggested that to fully caracterized banana peels as biodiesel it has to be tested using different oil at different parameters.

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