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Effect of $ZnCO_3$ as Heterogeneous Catalyst in the Production of Biodiesel Using Castor Oil

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ABSTRACT
Efforts have been made worldwide to find alternative fluids for industrial applications. Vegetable oil appears to be a perfect alternative, but using most of the vegetable oil as a feedstock made its use for industrial purposes challenging. The recent trend is to develop coolants/lubricants from non-edible seed oil. This work investigates the effects of zinc carbonate nanoparticles on viscosity of Trans-esterified Castor oil. The crude Castor oil was purified; Trans-esterified and nanoparticles were dispersed in the Trans esterified oil at concentrations ranging from 0.0% to 1.0% at 0.2% intervals. Fourier Transform Infrared (FTIR) spectra were used to examine the structures of the samples and Scanning Electron Microscopy (SEM) analyses were used to examine the surface morphology of the samples. Viscosities were examined. Among other things, it was found that a small amount of $ZnCO_3$ 0.2% nanoparticles in the oil could improve the viscosity of the fluid. The study achieved 95.4% yield using $ZnCO_3$ Nano-catalyst at 65°C, 0.8wt% catalyst loading, and 12:1 methanol oil ratio.

Keywords:
Castor oil,
FTIR,
XRF,
SEM,
Viscosity,
$ZnCO_3$.

INTRODUCTION

Increasing destructive environmental pollution and growing demand for world energy consumption have been aggravated as a result of transportation and growth of modernization and industrialization.The growing concerns about the environmental impacts of fossil fuels and their future availability and costs have resulted in the intensive development of alternative energy sources (Ahmad, 2021).

Biodiesel can work as an alternative form of fuel and can reduce our dependence on foreign suppliers of oil as it is produced from domestic energy crops. It is produced in local refineries which reduce the need to import expensive finished product from other countries (Mohammad *et al*, 2023). Biofuels refineries mainly use vegetable and animal fat converted into bio-fuel which releases less toxic chemicals, if spilled or released to the environment (Rehman *et al*, 2021). As compared to petroleum diesel,

Homogeneous catalyst is a process where the catalyst is in a different phase than the reactants, typically a solid catalyst with liquid or gas reactants.

They play a vital role in biodiesel production, making the process more efficient and eco-friendly, they speed up trans-esterification reaction, they allow easier separation of products (biodiesel, glycerol), and they enable catalyst reuse and reducing costs. Ismail *et al*, 2022

Castor has been recognized as new energy crop for the countries to grow their own renewable energy source with many promising benefits. With the growing interest in Biodiesel worldwide, there is need for national government to develop mechanisms for harnessing the potential of the fast growing industry and benefit from the growing international trade in Biodiesel (Kudelin & Kutcherov, 2021; Ismail *et al*., 2022)

The research objectives are; To investigate the effectiveness of zinc carbonate as a heterogeneous catalyst in the trans-esterification of castor oil, to evaluate the impact of zinc carbonate on the physical properties (viscosity, density, and flash point) of trans-esterified castor oil, to examine the effects of zinc carbonate on the thermal properties (scanning calorimetry) of trans-esterified castor oil and to study the

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influence of zinc carbonate on the rheological properties (flow behavior and viscoelasticity) of trans-esterified castor oil.

MATERIALS AND METHODS

Sample Preparation

Purification

200 ml of the castor oil was measured using measuring cylinder which was then freely-heated to 70^0C using hot magnet stirrer and thermometer for 15 minutes. 0.5 g of citric acid was measured and dissolved into 1.5ml of distilled water and then added to the heated oil sample which was continuously heated and stirred for 30 minutes at 80^0C.

4 ml of 8% NaOH (by dissolving 8g of NaOH in 100ml of distilled water) also was then added to the oil and continuously heated and stirred for 15 minutes at 90^0C.Then the temperature was increased to 100^0C, and 4g of activated carbon was added to each 100 ml of the oil sample, heated and stirred for 30 minutes.

Transesterification

60g of the castor oil was measured in 250sml of conical flask and then heated and stirred to a temperature of 60℃ to 65℃ on a hot magnetic stirrer plate. 0.6g of NaOH was measured using the electronic weighting machine and allowed to dissolve in 21ml of methanol and then added to the mixture and it was allowed to heat for 60 minutes with the stirrer on the hot magnetic plate. After 60 minutes of uniform stirring and heating on the hot magnetic plate maintaining a temperature of 65℃ which is the reaction temperature then it was poured into the separating funnel through a glass funnel. The mixture was then allowed to cool for about 40 minutes. Afterwards, it was observed to separate into two liquid layers. The upper layer was the biodiesel and the lower layer the triglycrol fatty acid.

Transesterification of Nano Fluid Preparation

60g of the castor oil was measured in 250ml of conical flask and then heated and 0.6g of NaOH and 0.2g zinc carbonate was measured using the electronic weight machine and allowed to dissolve in 21ml of methanol and then added to the mixture and allowed to heat for 60 minutes with the stirrer on the hot magnetic plate. After 60 minutes of uniform stirring and heating on the hot magnetic plate maintaining a temperature of 100℃, then it was poured into the separating funnel through a glass funnel. The mixture was allowed to cool for about 30 minutes. Afterwards, it was observed to separate into two liquid layers. The upper layer was the biodiesel and the lower layer was triglycrol fatty acid. The same procedure was applied to 0.2g, 0.4g, 0.6g, 0.8g and 1.0g zinc carbonate.

RESULTS AND DISCUSSION

SEM of Zinc Carbonate

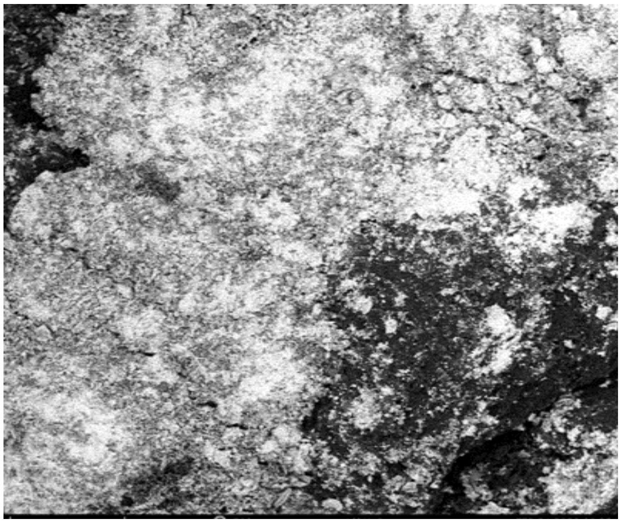

Figure 1: SEM of zinc carbonate at the magnification of 1000X.

Figure 1 revealed the SEM of the $ZnCO_3$ Nano-particle. It indicates the presence of dispersed particle and cloud structure. This is similar to the result obtained by Bureta *et al.*, (2021); Sarret *et al*, (2006) and Liang *et al*, 2022.

XRD OF $ZnCO_3$

X-Ray Diffraction provides information on the crystal structure and phase composition of the catalyst which shows that zinc carbonate sparkling with hexagonal crystal system.

XRF OF $ZnCO_3$

Table 1: Percentage concentration of the element

Elements	ZnO	C	Al	Ar	Fe	Cd	Ru	Loss of Ignition
Percentage	95.93	02.01	00.75	00.70	00.30	00.25	00.05	00.01

This result indicates that the zinc carbonate Nano-particle used in this study have a purity of 95.93%. The loss when starting the engine is 0.01%.

The table 1, indicate that the major elemental concentration in the zinc oxide was zincite. This result is analogous to the research carried out by (Levine *et al*, 2017). Li *et al*, (2025) Therefore it can be used as catalyst in the production of biodiesel and other biomaterials.

CHARACTERIZATION

Infrared Spectral Analysis of Trans-esterified Castor Oil

The band with peaks 650 to 1400 cm^{-1}signifies C-O bond then 1500 to 1800cm^{-1} describe C=O bond while 2700 to 3000 cm^{-1} described C-H stretching and finally from 3000 to 3700cm^{-1}show OH bond. Here C-O and C=O indicate the presence of ester or ether group in the sample (Isma'il *et al*, 2022).

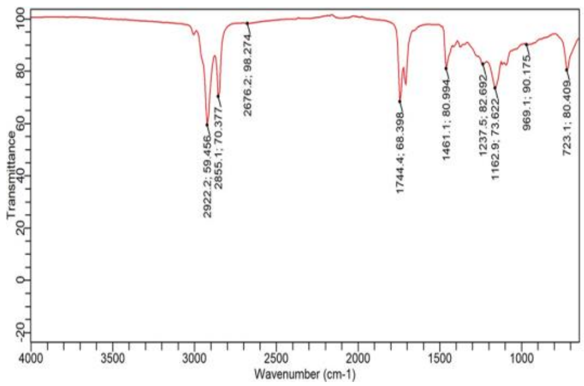

Figure 2: FT-IR Spectra of trans-esterified castor oil.

The spectra of Figure 2 confirmed the presence of biodiesel (ester) at 723.80409, 1162.73622 and 1461.80994 peaks which shows significant improvement on the castor oil after trans-esterification in accordance with the result of (Durumin-iya *et al*, 2024).

Viscosity of the Sample

Figure 3 shows that the viscosity of biodiesel extracted from castor oil was reduced from 137 mpas to 91 mpas by the trans-esterification process. The viscosity decreased with increasing temperature. This is because as the amount of Nano-particles in the liquid increases, more Nano-particles are propelled to the liquid surface and try to approach each other. This exerts a strong, Nano-fluids cohesive force between the molecules and, as a result, increased the surface tension. Show that the viscosity of trans-esterified castor oil at 70°C is 36 mpas which is lower than the specified value 65mpas of standard motor oil given by the American society for testing material (ASTM) at 70°C.

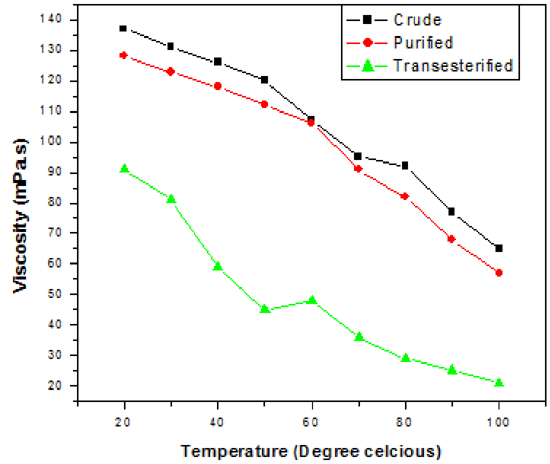

Figure 3: Viscosity of castor oil against temperature catalyst

The addition of Nano-particles led to an additional reduction in the viscosity of the liquid. Similarly, percent concentration shows a significant effect in decreasing the viscosity of the fluid. In general, as the temperature increases, the viscosity of the sample decreases and the time they spend in contact with their nearest neighbour decreases. Thus, with increasing temperature, the average intermolecular forces decrease. This was similar to the result obtained by Jamo *et al*., (2023).

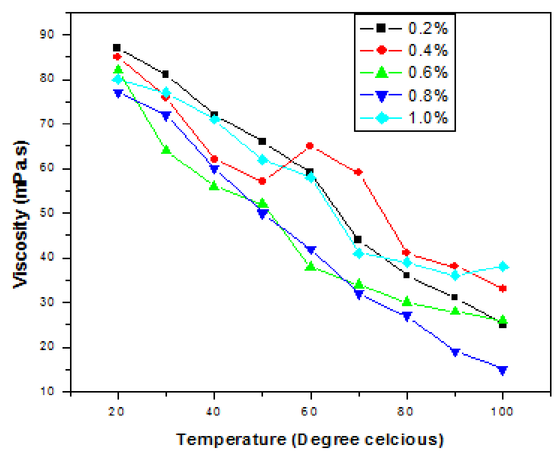

Figure 4: Viscosity of trans-esterified castor oil.

Smooth conduction and fluid flow are properties of insulating fluids as a result of low viscosity, which has necessitated additional study of this physical property. In order to ensure the effective cooling of transformer cores and windings, capacitors, regulators, pumps, etc., the viscosity of the oil has been systematically studied as shown in Figure 4; From this it was observed that the viscosity decreases with increasing temperature from 20°C to 100°C and it was observed that the viscosity of all samples at 70°C gave an optimal result as it is close to the ASTM standard.

CONCLUSION

The chemical properties of $ZnCO_3$ nanoparticles were studied by XRF. The XRF result shows that ZnO accounts for 95.93% of the sample. The morphological properties of the $ZnCO_3$ Nano-particle were also studied by SEM. The result showed that $ZnCO_3$ is dispersed particle with cloudy structure. The FTIR result shows that ester was produced between 650 cm^{-1} and 1400 cm^{-1} peak. The viscosity of the Castor oil was analyzed via viscosity for the crude, purified and trans-esterified Castor oil. The result shows that the viscosity of the crude oil is high. It has also been found that the viscosity of the Castor oil decreases after purification and subsequently after the trans-esterification. It was also found that the viscosity of the trans-esterified oil decreases as the concentration of the Nano-particles increases, with addition of 0.8% Nano-particles the optimal value of viscosity was achieved with a value of 15mpas. The study achieved 95.4% biodiesel yield using $ZnCO_3$ at 65°C, 0.8% catalyst loading, and 12:1 methanol oil ratio.

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