Effect of Vegetable Oil Viscosity on Biodiesel

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***Abstract*—** Vegetable oil is benign contribution to renewables owing to its reusability, sustainability, cost and environmental friendliness. These vegetable oils have many characteristic and properties that favors reaction stages needed to produces energy. The appearance, texture, impurities cloud point, pour point temperatures, viscosity and density of the fluid offer them as a good candidate viable for biodiesel production. Because one key challenge for efficient combustion of fluids is viscosity, this paper investigates vegetable oil viscosity and how it contributes to the production of biodiesel. The Vegetable oil used was tested between 313 -338k and confirmed that increasing temperature reduces the viscosity of oils and ultimately drive the production of biodiesel forward. The measured viscosities ranged from about 3.74 to 5.75 Centistokes (cst.). Fluids which undergo rapid deformation with heat tend to react faster when mixed with alcohol.

***Keywords*—** vegetable oil, biodiesel, viscosity.

I. INTRODUCTION

Biodiesel processing is done with any of these methods: transesterification, hydrolysis, pyrolysis, micro emulsion, supercritical process, and can involve the use of ultrasound, heat, and mechanical mixing at different environmental conditions. Transesterification is an efficient process for making biodiesel when vegetable oil and alcohol reacts to form ethyl esters and glycerin. The two proponents are vegetable oil(waste/new) and alcohol both of which have different viscosities. Viscosity is a property which determines the flow characteristic and in the case of biodiesel production the ability to mix and form new reactants. This reactant formation is highly influenced by production parameters which includes; temperature, molar ratio, concentration and the amount of catalyst used. Because vegetable oil contributes towards the greater percentage of the reactant, it is therefore important to understand how the properties associated with the oil impacts the production process. These properties are; viscosity, density, boiling point temperature and the values of; saponification, peroxide and iodine (Zahir, E. et al., 2017). This paper focuses primarily on the viscosity content of the oil and its impact on biodiesel production. Ogwu et al., 2019 emphasized on the importance of viscosity in liquids as it applies to the production of substances in science and engineering. Similarly, Fadeyi et al., (2021) affirmed the potentials of agricultural for scientific work. This paper addresses observations considering vegetable oil viscosity before production.

II. BACKGROUND THEORY

Biodiesel production is highly dependent on the type of feedstock used, and thus the first stage of the process requires selecting, sourcing, and preparing the reactants. A significant factor used in the consideration of biodiesel production is the fatty acid content, which plays a significant role in the thermophysical properties of the oil, i.e., the viscosity and density. Free fatty acids in oils are key functions that are responsible for the viscosity and density of oils. It has been acknowledged by Awogbemi, Onuh, and Inambao (2019) that the density of oils was influenced by the nature of its saturation free fatty acids. Due to the molecular structure of liquids, energy applied, reaction proponents, flow condition and the state of the fluid causes significant changes in viscosity. It is these dissociations from the main bond of the fluids that causes these changes and the ability to transform into new substances/state. These breakdown or structural alteration impact on the density and viscosity of the oil. Although, biodiesel's density and viscosity variations have been reported on the final product, there is little documentation on how these changes are observed during the reaction stages and how the raw material viscosity impacts the production. Igbax et al., (2016) showed that at the molecular level, the potential to maintain the fluid structure without change, reveals an indication that bonding forces exist. These forces provide an understanding of why the viscosity is affected by changes in thermophysical properties. As previously stated, the viscosity has been indicative of the titrated value and the mass spectra analysis which provided more information about the free fatty acid content (Igbax, 2020). The property of viscosity is important, because the molecular transport affects the dynamics of the fluid, its movement, dilution, reaction and transformation. The viscosity of biodiesel is important as a determinant of product quality which translates to how it affects the pour/flow abilities. These characteristics, when deficient causes leaks and excessive wearing of engine parts. Viscosity has an impact on the raw material, it can also indicate or signal difficulty in processing, poor quality biodiesel, and low production efficiency. There are many advantages biodiesel fuel offer to automobiles; the lack of sulfur extends the life of catalytic converters, while the viscosity offer adequate lubrication of engine thereby increasing the life of the vehicle.

III. MATERIAL TESTING AND METHODS

The viscosity Measurement

Applying suitable manufacturer data and appropriate choice for spindle and tube sizes. Capillary tube viscosity measurement is done using a 10ml vegetable oil sample and inserted into the capillary tube while maintaining the temperature in a water bath. The efflux time is observed by the time it takes to move through the two different marked point and this should be multiplied by the tube constant. This gives the reading in centistokes (cst) and is equivalent to 1 mm2/s

$$\text{Viscosity (cst)} = \text{Efflux time x Tube constant} \qquad (1)$$

For the rotary spindle viscometer, the sample is poured in a 500 ml beaker to a level marked on the spindle. For oils that appear to be more viscous, slower speed selection is used, and vice versa. Spindle speed 30 rpm and Location L1 was used for this work. A corresponding centipoise reading is noted within the range of speed and spindle number. Centipoise (cP) is equivalent to 10 10-3 N s/m2.

Similarly, for conversion and comparison between Centipoise and centistokes, density measurement is needed to get the specific gravity and is done using hydrometer to find the immersion displacement (x) on the hydrometer in a 500ml cylindrical tube.

$$\text{density of oil } \frac{\text{kg}}{\text{m3}} = (\text{specific gravity e} - 3) * \text{density of water } \frac{\text{kg}}{\text{m3}} \qquad (2)$$

$$\text{Specific Gravity of oil } = (x) * \text{density of oil} \qquad (3)$$

$$\text{Specific Centipose } = \text{Centistokes} * \text{Specific Gravity of oil} \qquad (4)$$

Standard measurement of fluids is shown in Table 1.for both reactant and product of biodiesel process.

Table 1: *Standard properties of reactants and product used in Biodiesel Production*

S/N	ITEM	TEMPERATURE ^0C	VISCOSITY cst	VISCOSITY cp	DENSITY Kg/m^3	BOILING POINT ^0C	REMARK
1	BIODIESEL	60^0C	4.48	3.17	0.8579	315-380 ^0C	LIQUID
		40^0C	7.03	6.13	0.8796		
		25^0C	10.73	9.49	0.8834		
2	METHANOL	60^0C	0.465	0.3710	0.7528	64.6 ^0C	LIQUID
		40^0C	0.585	0.4480	0.7771		
		25^0C	0.694	0.5680	0.7913		
3	VEGETABLE OIL	60^0C	20.85	18.8	0.890	120-140^0C	LIQUID
		40^0C	37.12	34.9	0.901		
		25^0C	66.45	62	0.912		
4	GLYCERINE	60^0C	110.4	81.3	1.3890	290 ^0C	LIQUID
		40^0C	354.79	285.47	1.2489		
		25^0C	1064	946	1.2580		

Note: "Prediction of the density and viscosity in biodiesel blends at various temperatures," by L. F. Ramírez-Verduzco, B. E. García-Flores, J. E. Rodríguez-Rodríguez, and J.A Del Rayo, Fuel, 90(5),1751-1761. https://www.sciencedirect.com/science/article/abs/pii/S0016236110006927, Copyright © 2011 Elsevier Ltd. All rights reserved. "Viscosity of glycerol and its aqueous solutions," by J.B. Segur and H. E. Oberstar, Industrial &EngineeringChemistry, 43(9),2117-2120. https://pubs.acs.org/doi/pdf/10.1021/ie50501a040, Copyright ACS Publications. All rights reserved. https://www.engineeringtoolbox.com/absolute-viscosity-liquids-d_1259.html

For liquids, the relationships between viscosity and temperature are inversely proportional and can be plotted using the Arrhenius equation. When oils are processed to biodiesel, the reaction creates different changes in viscosity of the mixture and leads to the formation of different products.

K=Ae^(-Ea/RT) (5)

The Arrhenius temperature viscosity relationship is shown in equation 6 below.The activation energies used were sourced from Noureddini and Zhu (1997) to produce the working relationship as the viscosity is measured. Table 2.1 show the relation when the application of equation 6 is applied.

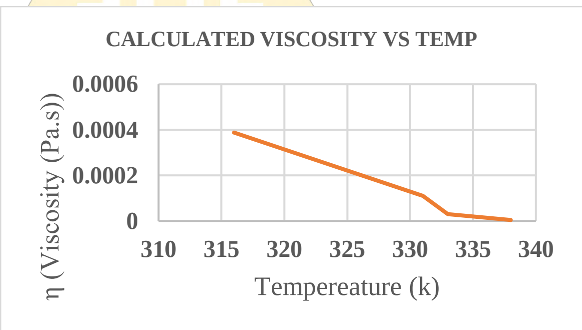
$$\eta=Ae^{(-Ea/RT)} \quad (6)$$

In this case k, the rate of reaction is replaced with η, the calculated dynamic viscosity of the mixture, while A, the pre-exponential factor can be represented by the infinite-temperature viscosity and measured as η∞ during the experimental process. Table 1.0 & 1.1 shows different fluid viscosities that is associated with biodiesel production. These fluid properties provide an understanding of what transpires when the fluids are mixed, as changes is being observed with the formation of new products with different viscosity level. The different fluids used in biodiesel production have different properties; viscosity, density, boiling point, etc., which changes when subjected to physical activities; heat and friction (colliding of molecules) to combine and form new products. The solutions gotten from the calculations provide the relationship of viscosity and the impact of activation energy as a function of temperature in equation 7.

$$\ln\eta=\ln A+Ea/RT \quad (7)$$

Table 2: *Viscosity Arrhenius values (mixture ratio 6:1) Ln η = Ln A + (- Ea/RT)*

s/n	A (Viscosity) Pa.s	Ea/RT	Ln A	η (Viscosity) Pa.s	Pre Expo Factor	Ea KJ/Kmol	Temp k
1	0.017	-3.78	-4.07454	0.000388	0.022813	9932	316
2	0.013	-4.78	-4.34280	0.00011	0.008424	13145	331
3	0.006	-5.29	-5.11599	3.03E-05	0.005054	14639	333
4	0.005	-7.07	-5.29831	4.26E-06	0.000853	19860	338



IV. DISCUSSION

The basic challenge with biodiesel production is to ensure that the reacting substances mix and form new products (biodiesel and glycerin). Poor mixing implies low yields, and unreacted oils and methanol are noticed at different levels. It is evident that oil and alcohol take a long time to mix in the absence of a catalyst, and hence this causes a slow reaction.

The Vegetable oil used was tested between 313 -338k and confirmed that increasing temperature reduces the viscosity of oils and ultimately drive the production of biodiesel forward. The measured viscosities ranged from about 3.74 to 5.75 Centistokes (cst.). Vegetable oils with a deeper/darker color appearance needs more adjustment to the processing parameters. When free fatty acid content is high a result lowering in yield is expected. Fluids (vegetable oil) which deform easily with application of energy increase the reaction progress in biodiesel production.

V. CONCLUSION

This work show that the changes in vegetable oil viscosity has an impact on the reaction of biodiesel production. Vegetable oils which exhibit a steep slope show the ability to react better with the production of biodiesel. Hence creating condition for better reactions with other reactant when making biodiesel. Similarly, when a subtle increase in the change in viscosity is observed, the formation of product signals an increase in the reaction progress. It is also worth nothing that these observations were taking ex situ while further research could focus on the response of in situ measurement during biodiesel production.

REFERENCES

[1] E. Zahir, R. Saeed, M.A. Hameed and A. Yousuf (2017). Study of physicochemical properties of edible oil and evaluation of frying oil quality by Fourier Transform-Infrared (FT-IR) Spectroscopy. Arabian Journal of Chemistry, 10, S3870-S3876.

[2] S. I Igbax (2020) Biodiesel yield based on the different oil composition and mixture ratio. Proceedings of Student Research and Creative Inquiry Day, 4.

[3] E. O. Augustine, O. E Stephen, and I. S Ityokumbul (2019). Design Fabrication and Testing of a Viscometer for Testing Viscosity of Liquids. International Journal of Engineering Research & Technology, 8(5), 659-663.

[4] O. Awogbemi, E. I. Onuh, and F. L. Inambao (2019) Comparative study of properties and fatty acid composition of some neat vegetable oils and waste cooking oils. International Journal of Low-Carbon Technologies, 14(3), 417-425.

[5] L. F. Ramírez-Verduzco, B. E. García-Flores, J. E. Rodríguez-Rodríguez, and J.A Del Rayo (2011). Prediction of the density and viscosity in biodiesel blends at various temperatures. Fuel, 90(5), 1751-1761.

[6] J.B. Segur and H. E. Oberstar (1951). Viscosity of glycerol and its aqueous solutions. Industrial & Engineering Chemistry, 43(9), 2117-2120. https://www.engineeringtoolbox.com/absolute-viscosity-liquids-d_1259.html

[7] H Noureddini and D. Zhu (1997). Kinetics of transesterification of soybean oil. Journal of the American Oil Chemists' Society, 74(11), 1457-1463.

[8] S. I. Igbax, N. Y. Nazir, E. A. Ogwu, (2016). The Use of Cooking Gas as Refrigerant in a Domestic Refrigerator. International Journal of Engineering Research and Applications (IJERA). Vol 6(3): 19-25.

[9] O. A Fadeyi, B. V. Omojeso & I. S Ityokumbul, (2021). A review of microfinance banks effects on smallholder development in Nigeria. African Journal of Agricultural Research, 17(9), 1249-1255.