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BIODIESEL KINEMATICS VISCOSITY ANALYSIS OF *Balanite aegyptiaca* SEED OIL

Babagana Gutti, Shittu S. Bamidele and Idris M. Bugaje
Department of Chemical Engineering, Faculty of Engineering, University of Maiduguri, Borno State, Nigeria
E-Mail: babaganagutti@gmail.com

ABSTRACT

Biodiesel is a renewable and promising fuel alternatively ear marked for use in Compression Ignition (CI) engines. For it to be applicable in CI engines, there are a number of quality tests required for its certification. Kinematics viscosity is one of the most significant test properties. The viscosity difference experienced between the oil and the biodiesel produced forms the basis of an analytical method use to determining the conversion of vegetable oil to methyl ester. This paper presents the definitions, test procedure specifications, and experimental results for the kinematics viscosity of *Balanite aegyptiaca* oil to biodiesel. In addition, the kinematics viscosity results have been used to extrapolate the Viscosity Index (VI) values of the produced biodiesel.

Keywords: *Balanite aegyptiaca*, viscosity, biodiesel, index, specification, engines, certification.

1. INTRODUCTION

Biodiesel is a renewable, alternative diesel fuel produced from vegetable oils, animal fats and recycled restaurant grease. This non-toxic, biodegradable liquid fuel consists of mono-alkyl esters of long chain fatty acids and may be used alone or blended with petroleum-based diesel fuels. The most common method for producing biodiesel is the transesterification of fatty acid glycerol esters, commonly referred to as triglycerides. Fats and oils are made up of triglycerides, which are chemically reacted with methanol using either sodium hydroxide or potassium hydroxide as a catalyst. The products of this reaction are mixed, long chain, mono-alkyl fatty acid methyl esters and glycerol (glycerin), which are then separated and purified. The resulting fatty acid methyl esters are biodiesel while the glycerol is often sold for use in soaps and other products. Biodiesel contains no sulfur or aromatic hydrocarbons and is almost 10% oxygen; making it an oxygenated fuel which aids combustion in fuel-rich circumstances (Van Gerpen, 2005).

The CI engine patented by Rudolf Diesel used large injectors to prevent clogging by the viscous, heavy fuels, which were unrefined petroleum and vegetable oils. Because of the size of the engines, large warships, like the HMS Queen Elizabeth class battleships, were among the first mobile users of Diesel's technology. In 1920's, technological changes made possible much smaller diesel engines, which required lower viscous fuels. The petroleum industry began producing inexpensive medium weight diesel fuels, especially shutting down the biofuel market (Mike, 2007).

Biodiesel that is 100% fatty acid methyl esters is called B100. The B100 biodiesel is recognized worldwide as an alternative fuel and qualifies for mandated programs in both the European Union (EU) and United States (US). Although there are many required tests, most producers use the kinematics viscosity test to see if there is conversion of oil to the biodiesel. The oil is usually having a higher viscosity value than the produced fuel. Standard methods ASTM D445 measure the kinematics viscosity in oil and B100 biodiesel (Sigma-Aldrich, 2009). If the fuel does not reduce in viscosity, then the biodiesel is either reworked or blended before further testing. Given the importance of kinematics viscosity test as a commercial and regulatory specification, it is necessary to have an additional specification relating to the viscosity test, that is, a recognized standard which can be referred to as a means of validating kinematics viscosity in dispute resolution processes. This brings about the issue of viscosity index.

One of major concerns in using *Balanite aegyptiaca* seed oil as a feedstock for biodiesel production is its high kinematic viscosity point. The kinematic viscosity is "the resistance to flow of a fluid under gravity" and is expressed in typical units: Centistokes (cSt) = mm^2/sec, Stokes (St) = cm^2/sec, and Saybolt Universal Seconds (SSU or SUS).

High viscosity means high resistance to flow while low viscosity means low resistance to flow. Viscosity varies inversely with temperature. The relationship between temperature and viscosity typically follows the regression equation:

$$\log \eta = A + B/T + C/T/T,$$

Where

η = viscosity, T = absolute temperature (K) (NREL, 2009). Figure-1 shows the kinematic viscosity for various diesel and biodiesel fuel standards, along with a sample of reported measurements for various types of biodiesel - methyl or ethyl esters. Note that before transesterification the vegetable oil input to biodiesel production has kinematic viscosities somewhere in the 30-50 centistokes range at 40°C which would display off the right side of the chart. Automobiles that run on Straight Vegetable Oil (SVO) pre-heat the oil to bring the vegetable oil viscosity down to below 10 centistokes.

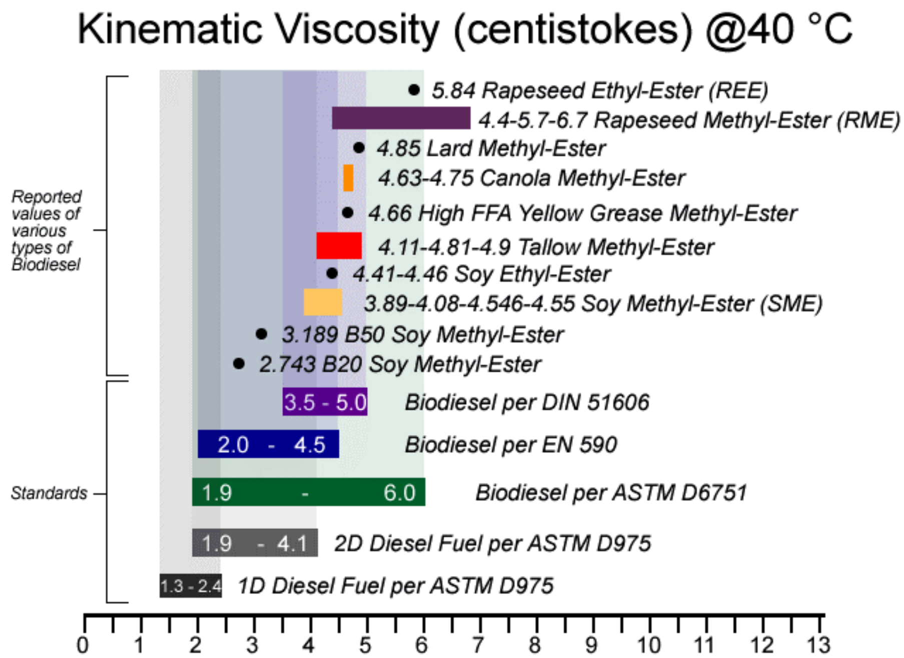

Figure-1. Kinematic viscosity for various diesel and biodiesel fuel standards adapted from (Brevard biodiesel).

It is evident that there are various problems associated with vegetable oils being used as fuel in CI engines, mainly caused by their high viscosity. The high viscosity is due to the large molecular mass and chemical structure of vegetable oils which in turn leads to problems in pumping, combustion and atomization in the injector systems of a diesel engine. Due to the high viscosity, in long term operation, vegetable oils normally introduce the development of gumming; the formation of injector deposits, ring sticking, as well as incompatibility with conventional lubricating oils (Praminik, 2003; Bugaje, 2008; Emil *et al*., 2009). Similarly, lower viscosity or a significant reduction in viscosity can result in loss of lubricity causing excessive wear, higher mechanical friction causing high heat generation which may cause high energy consumption, reduction of oil film will cause friction between moving parts in the system causing particle contamination. Therefore, a reduction in viscosity is of prime importance to make vegetable oils a suitable alternative fuel for diesel engines.

Praminik (2003) and Emil *et al*., (2009) have pointed out that the problem of high viscosity of vegetable oils can be approached in several ways, such as; preheating the oils, blending or dilution with other fuels, thermal cracking/pyrolysis, ultrasonically assisted methanol trans-esterification and supercritical methanol trans-esterification. All these have been used to reduce the viscosity and make them suitable for engine applications. This paper discussed the findings of kinematics viscosity and the viscosity index from the experiments carried out in producing biodiesel from *Balanite aegyptiaca* oil at temperatures of 40°C and 100°C.

2. MATERIALS AND METHODS

The materials used in the experiment included *Balanite aegyptiaca* oil, potassium hydroxide, methanol, a separating funnel and viscosity bath were used as equipment.

METHODS

Base catalyzed transesterification of the oils

Two hundred and fifty milliliters equivalent to 221.55 g or 0.254 mol of *Balanite aegyptiaca* oil, 44.31 g of methanol (1.383 mol) and 3.32g KOH (1.5% W/W with respect to the *Balanite aegyptiaca* oil) was mixed. The oil was preheated to about 60°C (140^{O}F), prepared Methanol and KOH (Methoxide) was added carefully and mixed well for 20-30 minutes. The mixture was poured into a separating funnel and allowed to settle for 12- 24 hours. The ratio of the recovered methyl esters to the oil was used to calculate the yield of biodiesel. The kinematics viscosity of the oil and biodiesel produced is determined using ASTM D445 method.

Kinematics viscosity determination by ASTM D445

The kinematics viscosity is equal to the dynamic viscosity divided by density. It is a basic design specification for the fuel injectors used in diesel engines. Too high viscosity will not allow the injectors to perform properly. The determination of kinematics viscosity was carried out by introducing about 50 ml of sample oil into a clean dried viscosity tube. This is done by inverting the tube thinner arm into the oil sample and then using suction force to draw up the oil to the upper timing mark of the viscometer. The viscometer was placed into a holder and inserted into a constant temperature bath set at a desired temperature of 40°C and 30 minutes for the sample to come to the bath temperature. The suction force was then applied to the thinner arm to draw the sample slightly above the upper timing mark. The afflux time was recorded by timing the flow of the sample as it flow freely from the upper timing mark to the lower timing mark. The kinematics viscosity (v) is calculated by means of the following equation (1) adapted from Sandford *et al*., 2009:

$$V = c \cdot t \tag{1}$$

Where

V = Viscosity in (mm^2/s or cSt)
t = Time in seconds
c = Viscosity tube constant

This test was also carried out at a temperature of 100°C to allow the possibility of determining the viscosity index of VI- ASTM D2270 of the oil and fuel. Table-1 gives the viscosity tube constants for Canon-Fenske viscometer used in the calculation of viscosity of oil sample and biodiesel produced from Balanite aegyptiaca seed.

Table-1. Canon -Fenske viscometer constants.

Tube series /no.	Constants @ 40°C	Constants @ 100°C
150/3525	-	0.023871
150/277	-	0.04414
200/62067	0.09757	-
200/62060	0.1029	-

From (ASTM, 1975), the viscosity index value of the oil was interpolated from the chart using both values of temperatures (100°C (7.91 cSt) and 40°C (34.42 cSt) to get 213 cSt. The viscosity index value of the biodiesel from the chart using both values of temperatures (100°C (2.07 cSt) and 40°C (5.42 cSt) to get 239cSt.

3. RESULTS AND DISCUSSIONS

Table-2 presents a summary of the important results for the kinematics viscosity investigated.

Table-2. Kinematics viscosity of *balanite aegyptiaca* oil and its biodiesel (B100) according to ASTM 6751.

Test property	Test method	ASTM D 6751 limits	ASTM D 975 limits (Diesel fuel)	*B. aegyptiaca* oil	*B. aegyptiaca* Biodiesel
Kinematics viscosity, 40°C, mm^2/s	D 445	1.9 - 6.0	1.9 - 4.1	34.42	5.42
Kinematics viscosity, 100°C, mm^2/s	-	-	-	7.91	2.07

One of most important properties of biodiesel is kinematics viscosity. Table-2 shows the oil and methyl ester kinematics viscosity values. Result shows that there is change in viscosity value from the oil into the methyl ester conversion. The kinematics viscosity of the oil at 40°C and 100°C are 34.42 and 7.91 cSt (mm^2/s), while that of the converted oil at 40°C and 100°C are 5.42 and 2.07 cSt (mm^2/s), respectively; this is its resistance to flow. High viscosity means high resistance to flow while low viscosity means low resistance to flow. It can be seen that the oil viscosities are on the high side when compare to the ASTM standard value expected for an engine to work properly, subsequently the viscosity can be seen to vary inversely with temperature. (Emil *et al*., 2009) has quoted a different source to have noted that Viscosity increased with molecular weight but decreased with increasing unsaturated level and temperature. So the viscosity of *Balanite aegyptiaca* oil must be reduced for biodiesel fuel application in engine. High viscosity of the oil seed is not suitable if its use directly as engine fuel, or else it will result in operational problems such as carbon deposits, oil ring sticking, thickening and gelling of lubricating oil as a result of contamination by the vegetable oils. For the viscosity index, it can be deduced that the higher the viscosity value the lower the viscosity index.

4. CONCLUSIONS

With increased interest in biodiesel production, the issue of product quality will be an on-going concern. This study has demonstrated that the determination of kinematics viscosity provides excellent parameter for compliance with ASTM specifications. Transesterificaation of vegetable oil is a suitable approach to completely fulfilling the kinematics viscosity specifications for renewable diesel. This is because the high value of the viscosity of the pure vegetable oil observed from the result give rise to a number of technological and operational issues. To address these issues, transesterifcation of the oils was carried out; this is a very important step, since it strongly affects the kinematics viscosity.

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