Assessment of Thermophysical Properties of Biodiesel from Sunflower Waste Cooking Oil and its Blends for Proposed Diesel Engines Assessment

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Abstract:- Relevance of thermophysical properties in biodiesel industry has been reported to be relevant for modelling and diagnostic tools. Limited information is available in literature for kinetic and combustion modelling. The research is undertaken to bridge the gap in knowledge by investigating density, viscosity, flash point and sulphur content of biodiesel from waste cooking oil. In this research, density (Den), viscosity (KV), flash point (FP) and sulphur content (SC) of sunflower waste cooking oil biodiesel (SWCOB) and automotive gas oil (AGO) blends were studied. The influences of blend content and temperature variation were investigated on the Den and KV. Changes in the FP and SC as a result of biodiesel fraction (B0, B10, B20, B40 and B100) were evaluated using biodiesel standard protocol. The Den, KV, FP of the fuel types increased with blending fraction while that of SC decreased. The Den of the fuel types increased while that of KV decreased with an increase in temperature. Owing to high regression values, the mathematical developed can be employed as a combustion tools for performance behaviour of diesel engine fuelled by waste cooking oil biodiesel/diesel blends.

Keywords: Sulphur content, waste cooking oil, transesterification, optimal, properties

Introduction

Continuous militancy attack on both onshore and shallow fields coupled with hike in the price of automotive gas oil/diesel fuel as well unfriendly gaseous emission emanating from diesel vehicular engines and power plant have ignited the interests of stakeholders and researchers for sustainable and environmental alternative fuel [1, 2]. Hence, alternate fuel from lipid feedstocks has to be explored as palliative measures before the fossil fuel gets exhausted. Outstanding superior properties of biodiesel resulting from transterification have paved way for global attraction for its usage in vehicular diesel engines without modification [3]. Biodiesels have been produced from spectrum of lipid feedstock such as fat, inedible and waste oil through transesterification process [4]. Yield of (m) ethyl ester has been optimized and manufacturing expenses have been reduced via optimization technique [5]. The emergence of waste cooking oil as a preferred biodiesel feedstock has been attributed to its ability to reduce cost of biodiesel production, reduction in disposal and not stressing food production [6].

As the adoption of biodiesel in automotive diesel engine is gaining attention, scientists and stakeholders have started utilizing thermophysical properties in their theoretical, kinetic and combustion modelling [7]. Several researchers [8-11] have expressed fuel related properties with biodiesel concentration or temperature. Their results have indicated high regression coefficient. Prior information concerning thermophysical can furnish researchers information needed to conduct engine test, combustion and emission behaviour [9]. From the exhaustive review conducted, regression models for systematic correlation of density, density flash point and sulphur content of sunflower waste cooking oil biodiesel (SWCOB) are rare in published journals. Since the information related to the afore-mentioned properties are crucial for diagnostic tools in biodiesel industry, a study is undertaken in that regards. The aim of the study is to study effect of temperature and biodiesel content on density and viscosity. The research is further undertaken to examine the variation of flash point and sulphur content with biodiesel fraction.

Materials and methods

Biodiesel synthesized from sunflower waste cooking oil (SWCO) in the Biotechnology Laboratory, Federal University of Agriculture, Abeokuta and fossil diesel (B0) purchased from Jocceco Filling Station, Warri, Delta State, Nigeria were employed as the alternate fuel and conventional diesel, respectively. Blends at proportions of 10% (B10), 20% (B20) and 40% (B40) on volume basis were prepared. Homogenous and consistency fuel types were ensured and the blending procedures were discussed elsewhere [2].

Densities and viscosities of the fuel types were obtained by employing density hygrometer (M50, India) and Chongquing viscometer (VST-2000, China) according to ASTM D1250 and ASTM D445, respectively. Moreover, densities of the fuel types were subjected to varying temperature ranged from 40-80 ^{o}C while those of viscosities were investigated at the varying temperature between 15 to 80 °C. Flash point (ASTM D56) was determined using Pensky-Markens flash tester (750/AUT, Italy) and sulphur content (ASTM D129) was detected using Horiba sulphur tester (SLFA 60, Japan).

Results and discussion

As can be observed in Figure 1, the density of fuel types increased as the biodiesel content increased in the blends. Density of B100 (883.8 kg/m^3) was higher than those of the blends (B10, B20 and B40) and the B0 (861.3 kg/m^3). The plot has a linear relation with biodiesel fraction with a high coefficient of determination (R^2 = 0.996). Fuel of high density has been indicated to cause high fuel consumption in diesel engines [12]. The high R^2 implies that not more than 0.4% of the experimental densities of the fuel types are not captured by the linear equation.

The variation of kinematic viscosity (KV) and biodiesel fraction is depicted in Figure 2. The KV of B100 (5.1280 mm^2/s) is higher than those of the fuel types (B10, B20 and B40) and B0 (4.7102 mm^2/s). There is a tendency for diesel engine fuelled with high density fuel to have slow rate in atomization and reduction in fuel losses [13]. Ref. [13] further recommended advancement in fuel injection pressure to compensate for the fuel losses. Owing to the increasing characteristics of the plot, a second-degree equation was found adequate to model the density-blend variation. The model was observed to have a R^2 of 0.978, indicating that less than 1.2% of experimental density was not captured by the density regression model.

The impacts of temperature on the Den and KV for diesel and B10, B20 and B40 blends as well as pure biodiesel are depicted in Figures 3 and 4, respectively. The Den of the fuel types quadratically increased with temperature. Densities of the fuel types are higher than those at temperatures 15 °C and 60 °C. Owning to these characteristics, second order degree models are found suitable to correlate the densities of the fuel types and temperature variation. The R^2 of density for B0 (0.998) is higher than that of B40 (0.995). The R^2 of B20 and B100 are equal (0.997). This implies that not less than 99.5% of density of SWCOB versus temperature variation can be captured by the model. The KV of the fuel types decreased quadratically with temperature. Owning to these characteristics, second order degree models are found suitable to correlate viscosities of the fuel types and temperature variation. The R^2 for the fuel types is 1. This indicates that majority of the kinematic viscosity and temperature was captured for all the fuel types.

Depicted in Figure 5 is the interaction between the flash point (FP) of the fuel types and biodiesel fraction in the blends. As the biodiesel concentration decreased in the fuel types, the FP decreased and vice-versa. This highlights that blends and B100 are easier to handle and transport than the conventional diesel [14]. Owing to the plot characteristics, a third-degree regression was found adequate to model the interaction between the FP of the fuel types at any biodiesel concentration with diesel. The R^2 of 0.999 from the third degree -regression model implies that not more than 0.1% cannot be captured by the FP regression model.

The sulphur content of the WCO biodiesel–diesel blends certified the density norms of the ASTM D6751and EN14214 (0.05) specification, even though the sulphur content of the SWCOB increased as the content of biodiesel in the blends increased. The third degree model equation was found adequate to correlate the variation of sulphur content and SWCOB–diesel fuel blends. The high R^2 (0.999) indicates that 99.9 % of the experiment was captured by the sulphur content model equation.

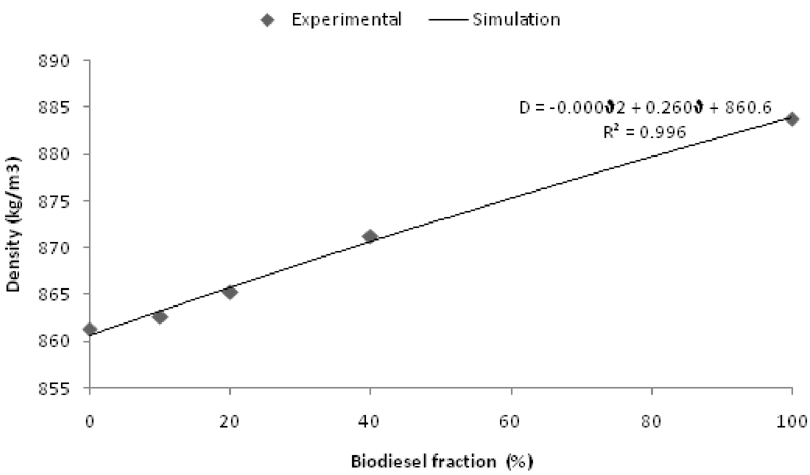

Figure 1 Variation of density with biodiesel fraction

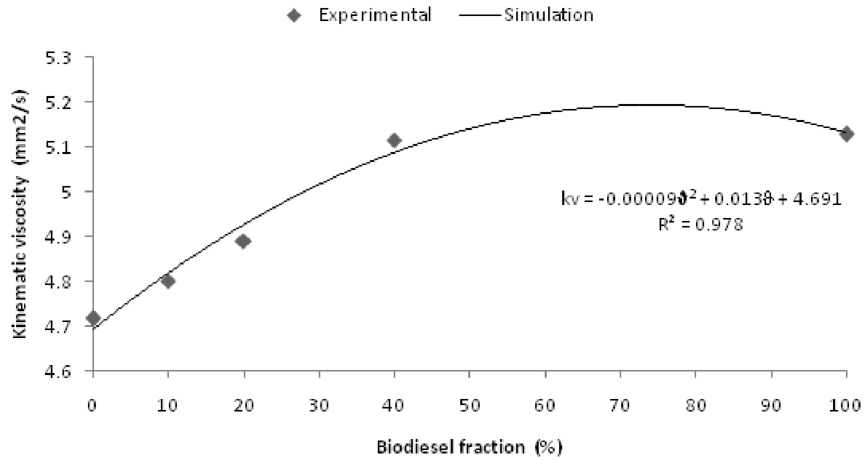

Figure 2 Variation of kinematic viscosity with biodiesel fraction

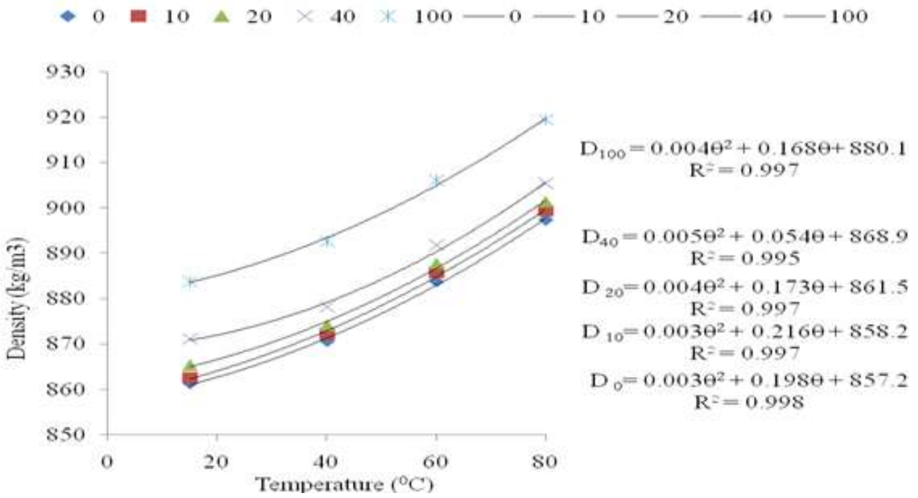

Figure 3 Variation of density of fuel types with temperature

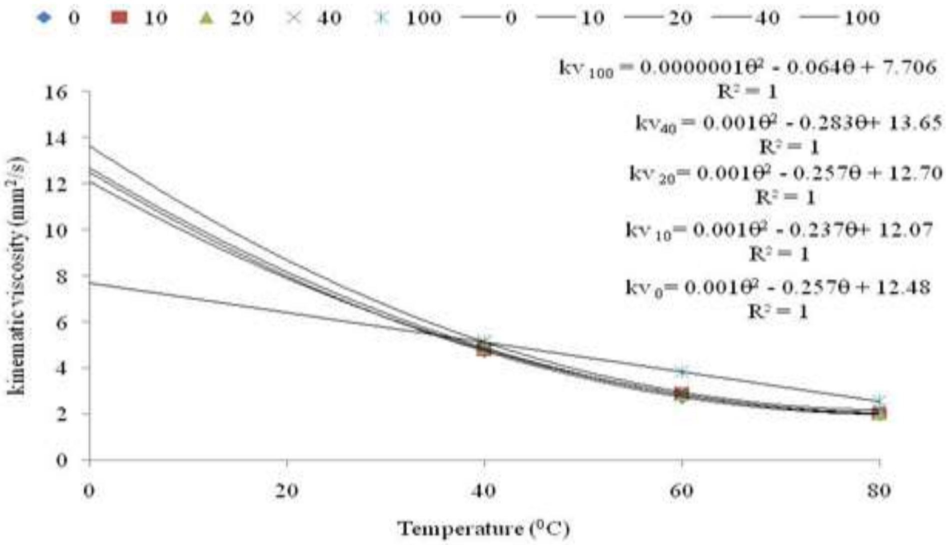

Figure 4 Variation of kinematic viscosity of fuel types with temperature

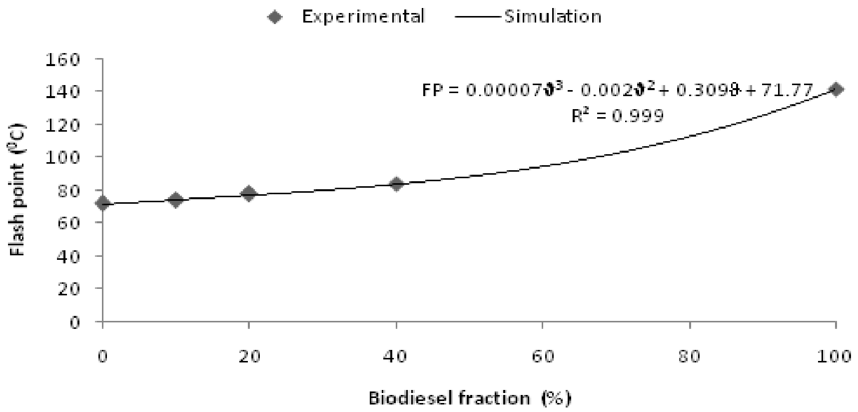

Figure 5 Variation of flash point with biodiesel fraction

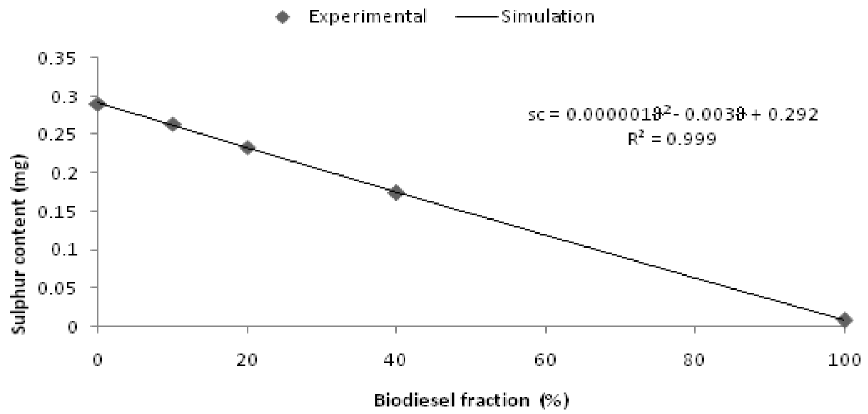

Figure 6 Variation of sulphur content with biodiesel fraction

Conclusions

Based on the experimental study and results, the following explanation can be deduced:

- The density, kinematic viscosity and flash point, increased while the sulphur content decreased as the percentage of waste cooking sunflower oil biodiesel increased in the blends.
- Experimental data of density, kinematic viscosity and flash point were correlated with the second degree order while sulphur content is modelled with second degree polynomial expressions.
- The proposed empirical models of blend fuel related properties can be explored to predict the properties of biodiesel-diesel at any blend content which will be a substantial assistance to design the fuel system of biodiesel engine

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