



SOME PHYSICAL PROPERTIES OF BIODIESEL BLENDS WITH GASOLINE

Ana PETROVIĆ¹, Vlasta VOZÁROVÁ¹, Ján CSILLAG¹, Matúš BILČÍK¹

¹*Department of Physics, Faculty of Engineering, Slovak University of Agriculture in Nitra*

Abstract

The physical properties of any fuel are significant factors which help to decide whether the oils are suitable for engine or not. The prediction of various properties of biodiesel or blends of biodiesel with gasoline is vital for the design of different systems of diesel engine. Therefore, this paper is dealing with characterization of viscosity and specific calorific value of biodiesels according to present standard testing methods. The basis of this work is experimental material research. The main aim is to evaluate effect of gasoline addition to biofuel. Dynamic viscosity showed high temperature dependence. Results presented that gasoline could effectively lower the viscosity. We concluded that calorific value depends on input raw material. It was concluded that almost all samples are following the standard specified by EN 14214 and ASTM D 6751.

Key words: *biodegradable fuels; gasoline; viscosity; specific calorific value.*

INTRODUCTION

As the primary liquid fuel – diesel is being used in many sectors e.g. transportation, power, agriculture etc. (Pantazi *et al.*, 2013). A significant role in the economic development of a country has the transport sector. This sector represents more than 70 % of the total diesel consumption. Industrial sector also consumes diesel for generator set and agricultural sector for water pumps. Diesel engine is being preferred for its high reliability, energy efficiency, durability and low operational cost by both manufacturers and users (Acharya *et al.*, 2017). But the vehicular pollution is a major source of air pollution which is a prime cause of different respiratory diseases and global warming. Beside this, the worrying problems are petroleum reserves and price increase of fossil energy. The current way of using fuels in transport cannot be characterized either as pure or as sustainable (Angelovič *et al.*, 2016).

The generation of "greenhouse gases" in the operation of motor vehicles may be impaired by the use of alternative drives or alternative fuels, respectively (Kosiba *et al.*, 2016). To compete with this critical situation, a good number of research have been conducted to find alternative to fossil fuels for eco-friendly condition. Biodiesel is considered to be a notable option for at least complementing conventional fuels (Aransiola *et al.*, 2014). The quality of biodiesel is regulated by standards, the two most utilized being ASTM D6751 in the United States and EN 14214 in the European Union. Many countries encourage the development and use of biodiesel. ASTM approves biodiesel blends, such as B5, for safe operation in any compression-ignition engine designed to be operated on diesel vehicles including electrical generators, trucks, tractors and boats.

Different researchers have studied the physical and chemical properties of biodiesel and blend it either experimentally or theoretically. Researchers proved that the diverse fatty acid composition of biodiesel has huge impact on properties, which provides an obvious effect on engine performance. Accordingly, it is necessary to research biodiesels according to present standard testing methods (Atabani *et al.*, 2013).

Most of the researchers reported biodiesel (BD) – gasoline (G) blends impact on gasoline compressed ignition (GCI) engine performance and emission (Putrasari & Lim, 2018; Adams *et al.*, 2013) or common rail diesel engine (Chen *et al.*, 2017). And these studies shown that BD – G blends have better low temperature fluidity and vaporization than biodiesel itself. Gasoline addition reduces smoke and ultrafine particle emissions (UFP), while the NO_x emissions increases a little. However, detailed study on physicochemical properties not yet been published. Hlaváčová *et al.* (2018) made the same conclusion. The specification for the biodiesel – gasoline blend fuel has lack of information. This paper is dealing with some physical properties – viscosity and specific calorific value.



MATERIALS AND METHODS

Selected biodiesel and biodiesel blends

Commercial gasoline (G) and Rapeseed methyl ester biodiesel (BD) and four gasoline-biodiesel blends (95 % BD + 5 % G (95:5), 90 % BD + 10 % G (90:10), 85 % BD + 15 % G (85:15) and 80 % BD + 20 % G (80:20)) were used in this study. The gasoline-biodiesel blends were prepared by a mixing/shaking process for about (3–5) min to produce homogeneous blends. This homogenization process was repeated before every measurement.

Methods and measuring equipment

Viscosity is the most important property of any fuel as it indicates the resistance of a material to shear or flow and it is strongly influenced by temperature. It therefore affects the operation of the fuel injection equipment and spray atomization, particularly at low temperatures when the increase in viscosity affects the fluidity of the fuel (Božiková *et al.*, 2016; Atabani *et al.*, 2013). Dynamic viscosity derived from Newton's law is characterized by a relationship:

$$\tau = \eta \text{ grad } v \quad (1)$$

where: $\text{grad } v = \frac{dv}{dh}$ - the size of velocity gradient (s^{-1}), τ - shear stress (Pa), η - dynamic viscosity (Pa.s).

The fuel as a liquid is said to exhibit ideal viscous flow or Newtonian behaviour. We can divide the viscosity into dynamic and kinematic. For liquids, dynamic viscosity is functionally dependent on temperature and pressure, decreases with ascending temperature and rising when pressure rises. The relationship of kinematic and dynamic viscosity states that the viscosity can be defined as the ratio of dynamic viscosity and density of liquid when measured at the same temperature:

$$\nu = \frac{\eta}{\rho} \quad (2)$$

where: η - dynamic viscosity (Pa.s), ρ - density (kg.m^{-3}).

Viscosity of most of the liquids decreases with increasing temperature according to Arrhenius equation (Hlaváč *et al.*, 2016).

$$\eta = \eta_0 e^{\frac{E_A}{RT}} \quad (3)$$

where: η - dynamic viscosity (Pa.s), η_0 - reference value of dynamic viscosity (Pa.s), E_A - activation energy (J.mol^{-1}), R - gas constant (J.K.mol^{-1}), T - absolute temperature (K).

Božiková & Hlaváč (2013) conducted research of rheological properties of rapeseed oil, where relation had exponential decreasing progress and it was described by modified Arrhenius equation. Viscosity of vegetable oil is typically ten times higher than petroleum based diesel. High viscosity leads to a poorer atomization and vaporization, formation of shoots, etc. (Atabani *et al.*, 2013). Lower viscosity implies better low-temperature performance (Alicke *et al.*, 2015; Joshi & Pegg, 2007). Other literature often presents kinematic viscosity data for biodiesel and its components, and these data are included in our work. Kinematic viscosity is prescribed in biodiesel standards. Often, the authors obtain whole curves to investigate temperature and blend concentration effects on viscosity.

Dynamic viscosity was measured with the Brookfield DV2T Viscosimeter. Measurements of the dynamic viscosity in the temperature interval from temperature 25 °C to 90 °C, are provided. In our case of measuring fuels, we used the ULA (0) spindle. All the samples had volume 16 ml. Accuracy of the viscosity measurement is ± 1.0 % of the full scale.

The specific calorific value of virtually all fatty acid methyl esters occurring in biodiesel exceed 35 000 kJ.kg^{-1} (35 MJ.kg^{-1}), the minimum specific calorific value prescribed in the European standard EN 14213 when using biodiesel for heating purposes. Specific calorific value q_s is the combustion heat calculated per unit of mass. It is reported in J.kg^{-1} .

$$q_s = \frac{Q}{m} \quad (4)$$

where: q_s - specific calorific value (J.kg^{-1}), Q - calorific value (J), m - mass (kg).



Energy value (expressed by calorific value) is an important parameter in the selection of a fuel. This is one of the important criteria as it affects the fuel consumption and output power. The energy value of biodiesel is generally lower than of diesel because of its higher oxygen content (Atabani *et al.*, 2013). The measurement method, used for measuring of the specific calorific value, is the calorimetry method with the IKA C 5000 calorimetric system. All samples had volume 0.400 mg and were measured ten times. Measurement accuracy is ± 0.1 %.

RESULTS AND DISCUSSION

From the measured data, we created graphical dependencies of the dynamic viscosity on temperature for all samples and the typical curves were listed in Fig. 1. The dynamic viscosity of 100:0, 95:5, 90:10, 85:15 and 80:20 at 40 °C is 5.35, 4.32, 3.83, 3.67 and 3.07 Pa.s, respectively. So the viscosity of biodiesel with larger ester head group is higher, which is also confirmed by other authors (Chen *et al.*, 2017; Moser, 2009). We deliberately measured the wider range of temperatures, because we wanted to obtain a full overview of the behavior of samples.

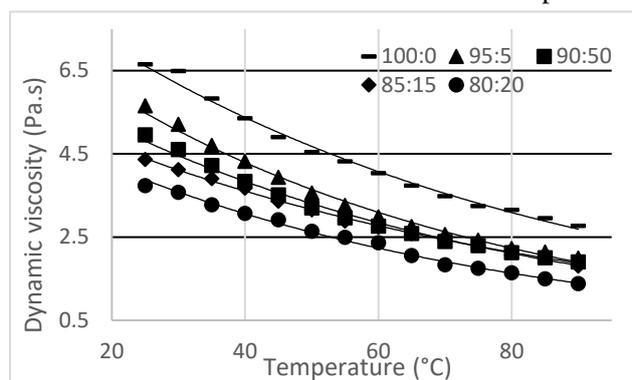


Fig. 1 Dependence of dynamic viscosity on temperature

Tab. 1 Overview of Viscosity Exponential Regression Equations and Determination Coefficients

Sample BD:G	Exponential regression equation	Coefficient of determination R^2
100:0	$y = 9.3465e^{-0.014x}$	0.9933
95:5	$y = 8.2474e^{-0.016x}$	0.9929
90:10	$y = 6.9824e^{-0.015x}$	0.9926
85:15	$y = 6.0912e^{-0.013x}$	0.9949
80:20	$y = 5.7446e^{-0.016x}$	0.9940

From Fig. 1, it can be seen that the measured viscosity values were different for individual samples. The greatest differences were at lower temperatures, where the viscosity is changed within a relatively wide range. Interestingly, the 100:0 sample, reaches the highest viscosity values. So as the temperature increased, the differences between the viscosities are getting smaller, and then the viscosity of 100:0 is greater than those of BD – G blends. In fact, a Newtonian behavior is always observed in this range. As expected, we see in Fig. 1, that the maximum viscosity of 100:0, 6.65 Pa.s is attained at the lowest temperature of 25 °C, and as the sample is heated the viscosity decreases, so we got final temperature of 90 °C and viscosity of 2.77 Pa.s. At temperatures at or above room temperature (25 °C), the ideal behavior of a biofuel is of a Newtonian fluid. The overall decrease in curve behavior is described by the exponential regression equations, which are listed in Table 1. Determination coefficients achieve high values for all samples. We can say, that the given regression equations precisely describe the graphical decreasing dependencies. These results confirmed the validity of Arrhenius exponential relationship. The statistical significance of the regression equation coefficients was tested on the level of significance $\alpha = 0.05$, in the Microsoft Excel software 2016 version 16.0.4266.1001, therefore, with the 95 % probability.

The viscosity tests showed an average precision of ± 0.08 mPa.s for the evaluated samples. The viscosity results are in accordance with the literature, where biodiesel have a higher viscosity than BD – G blends. According to Joshi & Pegg (2007) this is due to the composition of alkyl esters of long chain fatty acids. As the literature mostly report kinematic viscosity at 40 °C, in Table 2, we calculated it, according to the equation (2).

Fig. 2 shows a comparison of the kinematic viscosity values of the blends, biodiesel, and the standards applied to fuel mixtures. The ASTM D6751 standard establishes an acceptable range of viscosity for biodiesel from 1.9 to 6.0 $\text{mm}^2 \cdot \text{s}^{-1}$; while the EN 14214 standards defined the range between 3.5 and 5.0 $\text{mm}^2 \cdot \text{s}^{-1}$. Based on these data, $\nu = 6.176 \text{ mm}^2 \cdot \text{s}^{-1}$ for 100:0 is not fully acceptable in referenced standards, and therefore without blending cannot be used in the United States and Europe. Blend 95:5 is



in limits of ASTM, but still too high for EU. Other samples (90:10, 85:15, 80:20) fall under the cited standards.

Tab. 2 Density and calculated kinematic viscosity

Sample BD:G	Density 15 °C g.cm ⁻³	Density 40 °C g.cm ⁻³	Kinematic viscosity 40 °C mm ² .s ⁻¹
100:0	0.8838	0.8662	6.176
95:5	0.8774	0.8611	5.017
90:10	0.8714	0.8550	4.480
85:15	0.8655	0.8491	4.322
80:20	0.8612	0.8432	3.641

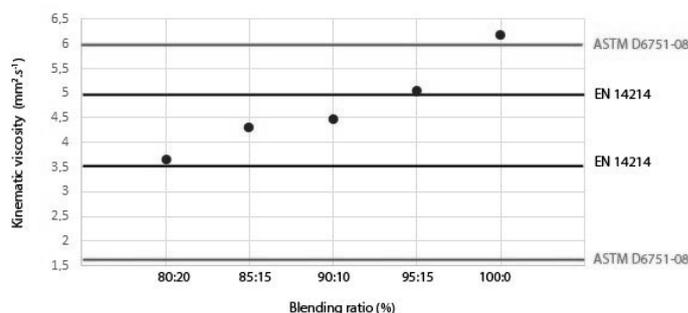


Fig. 2 Kinematic viscosity at 40 °C compared to standards EN 14214 and ASTM D6751

A comparison of some results in the present study and those in literature was also conducted. It was found that 100:0 possesses higher kinematic viscosity at 40 °C (6.176 mm².s⁻¹) than of *Atabani et al. (2013)* (4.5281 mm².s⁻¹), than that of *Karmakar et al. (2010)* with 4.439 mm².s⁻¹. *Chen et al. (2017)* has slightly higher viscosity of 6.01 mm².s⁻¹, but still below our result. In the same article he reports viscosities for blends 90:10 and 83:17, 4.76 mm².s⁻¹, 4.20 mm².s⁻¹, respectively. *Putrasari & Lim (2018)* got the result 4.229 mm².s⁻¹, while *Baczewski & Szczawinski (2011)* claim this value of viscosity 4.37 mm².s⁻¹.

With the increase in the percentage of gasoline present in the blends, the viscosity values slightly decreased. Reduction of the viscosity of 80:20 sample was the most remarkable among all reductions. The final stage of the life cycle of a fuel is its combustion in an engine. Calorific value is a crucial parameter in the selection of a fuel. It is important to mention that all samples were burned totally, so it was perfect combustion without ash.

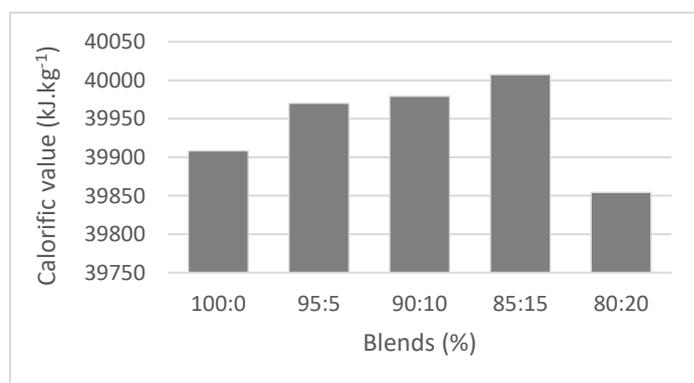


Fig. 3 Average values of measured Calorific value of fuel samples



The graphical representation of average values is shown on Fig. 3. It can be observed that sample 85:15 possesses the highest calorific value of 40007 kJ.kg⁻¹ followed 90:10 (39976 kJ.kg⁻¹), 95:5 (39970 kJ.kg⁻¹), 100:0 (39908 kJ.kg⁻¹) and finally 80:20 (39854 kJ.kg⁻¹).

Among the data presented in Fig. 3, it is found that 80:20 biodiesel blend contain lower calorific value (39854 kJ.kg⁻¹ on an average 39913 kJ.kg⁻¹) where the calorific value of other biodiesels is nearly 40000 kJ.kg⁻¹. We expected that the calorific value will increase with the increasing percentages of gasoline in blend, but even the measurement was repeated ten times for each sample, that was not confirmed for all blends. It should be noted, that the difference, between 80:20 and other samples, does not exceed 1 % of the average.

Tab. 3 Overview of descriptive statistics

Statistical parameter	100:0	95:5	90:10	85:15	80:20
\bar{q}_s	39908	39970	39979	40007	39854
\bar{S}	18.83	33.59	35.56	18.40	27.84
V_k (%)	0.047	0.084	0.089	0.046	0.069

It would also be interesting to research blends with even more gasoline, and see how the trend of calorific values would continue. The ASTM D6751 does not provide any limits for calorific values, but EN 14214 standard requires minimum of 35000 kJ.kg⁻¹. All samples are above the standards minimum value, thus they are acceptable.

It was found that our results of 100:0 (39908 kJ.kg⁻¹) possesses higher calorific value than 39790 kJ.kg⁻¹ in *Putrasari & Lim (2018)* or 37120 kJ.kg⁻¹ in *Adams et al. (2013)*. The one who find higher value is *Atabani et al. (2013)* 40195 kJ.kg⁻¹. *Chen et al. (2017)* declares 39390 kJ.kg⁻¹ for 100:0, 39980 kJ.kg⁻¹ for 90:10 blend and 40420 kJ.kg⁻¹ for 83:17 blend, where it was confirmed that with the increasing of gasoline percentage in blends the calorific value also increases.

CONCLUSIONS

This mainly experimental study highlighted some properties of various biodiesel–gasoline blends. To describe in detail those properties, it assumes the knowledge of the parameters that include the influence of the material on the storage and combustion processes. These properties include viscosity and calorific value. In the present work, attention was paid to the analysis of those parameters, in order to create the widest possible picture of biodiesel behaviour.

We emphasize that the temperature has an important impact on the microstructure, and hence they also have a strong influence on the rheology of the biodiesel. As temperature increases, dynamic viscosity has decreased. During measurement, dynamic viscosity, showed high temperature dependence. Results presented that gasoline could effectively lower the viscosity.

Further, during calorific value measurement, all samples were burned totally, so it was perfect combustion without ash. Based on above mentioned studied literature and our results, we can conclude that calorific value depends on an input raw material.

These properties can also help to predict the quality and performance of biodiesel in diesel or other engines. It was found that those properties of biodiesels are following the standard specified by EN14214 and ASTM D 6751. This research can also be motivation for further technical research and development of special filters for engine.

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Corresponding author:

Ing. Ana Petrovič, PhD., Department of Physics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, Nitra, 949 76, Slovak Republic, phone: +421 37641 5785, e-mail: ana.petrovic@uniag.sk