ORIGINAL PAPER

RHEOLOGICAL INVESTIGATION OF SOYBEAN OIL FROM SOYA BEANS

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Abstract. *The aim of the study was to investigate rheological properties of soybean oil. The soybean oil was investigated using a Haake VT 550 Viscotester at shear rates ranging between 3 and 120* s^{-1} *and measuring viscosity from* 10^4 *to* 10^6 *mPa·s when the* HV_1 *viscosity sensor is used. The temperature was ranged between 40 and 90°C and the measurements were made from 10 to 10°C. The accuracy of the temperature was* ± *0.1 °C. This paper proposes two new relations of dependence of log dynamic viscosity on the 1/T shear rates between 3.3 and 120* s^{-1}*. The constants A, B, and C were determined by Origin 6.0 software by fitting exponential or polynomial curves which were obtained from experimental data. The two proposed relationships give correlation coefficients close to one.*
Keywords: *rheology, soybean oil, models.*

1. INTRODUCTION

Soybean oil is renewable and clean energy source and can be a substitute to diesel fuel [1, 2]. The soybean oil can be produced from numerous oil seed crops and can have high energy contents [3]. Bio fuels from soybean oil are biodegradable and nontoxic, have low emission profiles and so are environmentally beneficial [4]. The added advantage of bio fuels is that they can be used for their own use by small farms [5], what is important for the development of sustainable agriculture. A major obstacle deterring their use in the direct-injection diesel engine is their high viscosity [6, 7].

The viscosity of the fuel is of great importance for the correct exploitation of the engine and fuel system. It determines the quality of spraying in the combustion chamber, the flow resistance of the fueled wires and filters, and affects the lubrication of the injection pumps [8, 9]. One of the ways to improve selected properties of crude soybean oil is to use common fuel additives [10-16]. These include conventional fuels (diesel) or cold starters (depressors).

Rheology is concerned with how materials respond to applied forces and deformations. Basic parameters of stress (force per area) and strain (deformation per length) are the key to all rheological evaluations [11]. Also, according to Adolfo F. et al., research, of the original vegetable oils studied by them, soybean oil was found to be more sensitive to thermal treatment, undergoing greater changes in its properties, especially in viscosity, which may increase considerably [12]. On the other hand, though the importance of oil industry, there are not enough researches on edible vegetable oils. So the necessity of working on this subject is clear.

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2. MATERIALS AND METHODS

Types of soybean oil used in this paper are produced from soya beans (*Glycine max*) produced in Romania. The soybean oil was investigated using a Haake VT 550 Viscotester at shear rates ranging between 3 and 120 s^{-1} and measuring viscosity from 10^4 to 10^6 mPa·s when the HV_1 viscosity sensor is used. The temperature ranged between 40 and 90 °C and the measurements were made from 10 to 10°C. The accuracy of the temperature was ± 0.1°C.

3. RESULTS AND DISCUSSION

Figs. 1-6 shows dependency of the log dynamic viscosity on the 1/T for studied soybean oil at shear rate 3.3 s^{-1}, 6 s^{-1}, 10.6 s^{-1}, 17.87 s^{-1}, 30 s^{-1}, 52.95 s^{-1}, 80 s^{-1} and 120 s^{-1}.

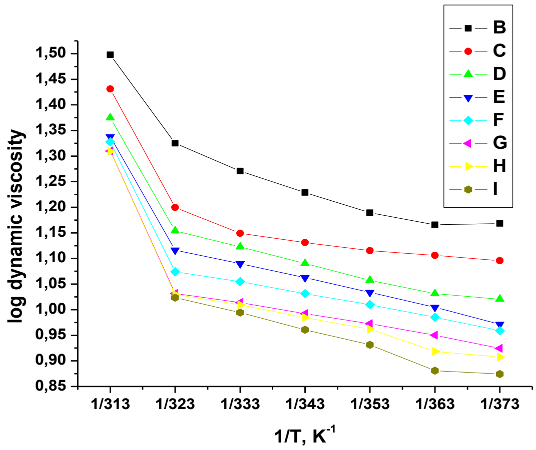

Figure 1. The correlation of log dynamic viscosity on the 1/T at: B – 3.3 s^{-1}, C – 6 s^{-1}, D – 10.6 s^{-1}, E – 17.87 s^{-1}, F – 30 s^{-1}, G – 52.95 s^{-1}, H – 80 s^{-1} and I – 120s^{-1}.

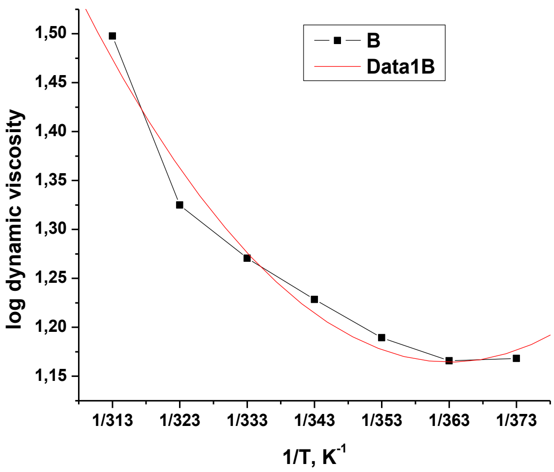

Figure 2. The correlation of log dynamic viscosity on the 1/T at 3.3 s^{-1} for right to B and 1B represents the polynomial fitting to B.

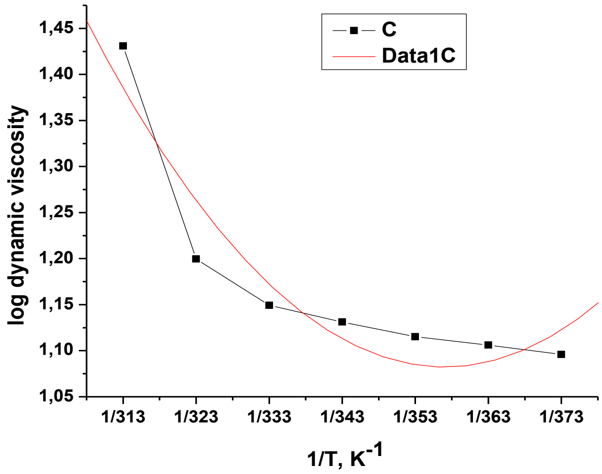

Figure 3. The correlation of log dynamic viscosity on the 1/T at 6 s^{-1} for right to C and 1C represents the polynomial fitting to C.

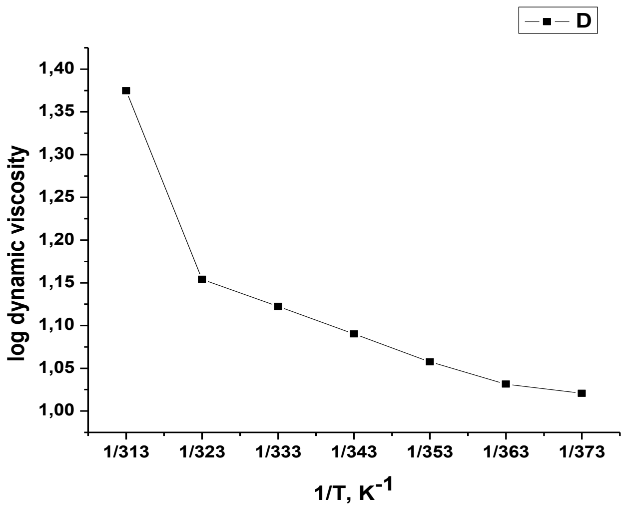

Figure 4. The correlation of log dynamic viscosity on the 1/T at 10.6 s^{-1}.

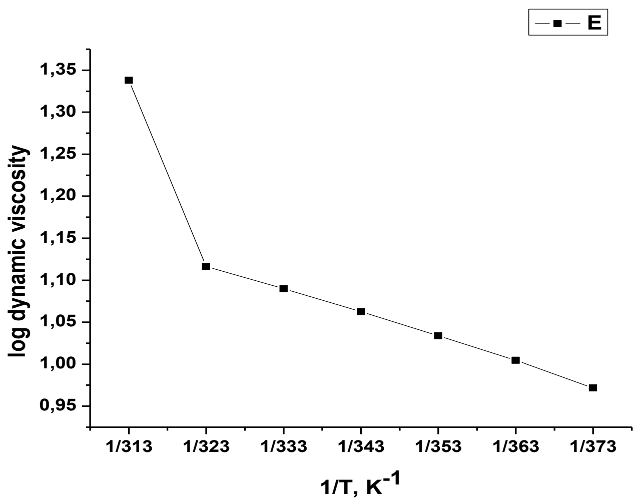

Figure 5. The correlation of log dynamic viscosity on the 1/T at 17.87 s^{-1}.

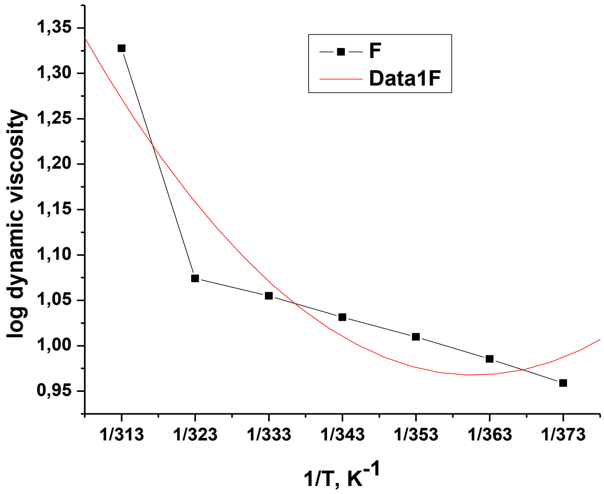

Figure 6. The correlation of log dynamic viscosity on the 1/T at 30 s^{-1} for right to F and 1F represents the polynomial fitting to F.

To elucidate the effect of temperature on the absolute viscosity the following equations (1) and (2) have also been used [13]:

$$\log \eta = A/T - B \quad (1)$$

$$\eta = A - B \log T \quad (2)$$

where T is the temperature absolute and A, B and C in the equations (1) to (2) are correlation constants.

The dependency of log dynamic viscosity on the 1/T for soybean oil at shear rate 3.3 s^{-1}, 6 s^{-1}, 10.6 s^{-1}, 17.87 s^{-1} and 30 s^{-1} (the black curves from Figs. 2-6) was fitting polynomial as shown in Figs. 2, 3 and 6. The polynomial dependence of natural log dynamic viscosity on the 1/T for soybean oil is described for equation (3):

$$\log \eta = A + B\cdot 1/T + C\cdot (1/T)^2 \quad (3)$$

The exponential dependence of natural log dynamic viscosity on the 1/T for soybean oil is described for equation (4):

$$\eta = A + B\exp(\log T/C) \quad (4)$$

Table 1. The shear rate, value of parameters of described by equation (1) and coefficient correlation for soybean oil.

Shear rate, s^{-1}	Value of parameters		Correlation coefficient, R^2
	A	B	
3.3	-0.0496	-1.4618	-0.9051
6	-0.0438	-1.3506	-0.8031
10.6	-0.0490	-1.3176	-0.8717
17.87	-0.0492	-1.2850	-0.8813
30	-0.0474	-1.2530	-0.8327
52.95	-0.0486	-1.2223	-0.8102
80	-0.0527	-1.2280	-0.8354
120	-0.0319	-1.0878	-0.9901

Table 2. The shear rate, value of parameters of described by equation (2) and coefficient correlation for soybean oil.

Shear rate, s^{-1}	Value of parameters		Correlation coefficient, R^2
	A	B	
3.3	-2.3679	-28.4729	-0.8574
6	-145.2299	-383.6237	-0.7705
10.6	-138.4227	-364.5819	-0.8261
17.87	-127.2864	-335.3264	-0.8324
30	-120.0516	-316.3096	-0.7871
52.95	-116.2889	-305.8871	-0.7658
80	-122.3339	-320.9883	-0.7843
120	-52.1047	-141.2674	-0.9912

Table 3. The shear rate, value of parameters of described by equation (3) and coefficient correlation for soybean oil.

Shear rate, s^{-1}	Value of parameters			Correlation coefficient, R^2
	A	B	C	
3.3	12.7459	-8450.0575	1.5418E6	0.9798
6	17.6634	-11810.7576	2.1038E6	0.9204
10.6	13.6789	-9179.9106	1.6653E6	0.9333
17.87	11.7219	-7864.4071	1.44113E6	0.9123
30	14.6387	-9858.8215	1.7780E6	0.8816
52.95	16.4793	-11157.4185	2.0019E6	0.8678
80	15.9083	-10821.9707	1.9529E6	0.8840
120	-0.5634	660.4037	-47271.3660	0.9834

Table 4. The shear rate, value of parameters of described by equation (4) and coefficient correlation for soybean oil.

Shear rate, s^{-1}	Value of parameters			Correlation coefficient, R^2
	A	B	C	
3.3	15.5288	2.2499E89	0.0123	0.9806
6	11.8706	8.4067E64	0.0169	0.9513
10.6	10.4947	5.7722E65	0.0168	0.9662
17.87	9.1036	5.6694E49	0.0223	0.9304
30	8.6803	2.7871E53	0.0207	0.9066
52.95	7.8925	4.7931E54	0.0202	0.8939
80	7.9304	8.6038E64	0.0169	0.9327
120	7.9628	7.0191E65	0.0167	0.8116

Tables 1-3 show that the value of parameters of the described by items equations (1)-(4) soybean oil and correlation coefficient, R^2. In Table 1 the value of A increases with the shear rate increase, the B parameter increases with the shear rate increase and the correlation coefficients are close to the unit. In Table 2 the values of A and B are variable and the correlation coefficients are not close to the unit. In Table 3 the values of A, B and C are variable and the correlation coefficients are close to the unit. In Table 4 the values of A, B and C are variable and the correlation coefficients are close to the unit.

4. CONCLUSION

The dynamic viscosity of soybean oil was determined at temperatures between 313 and 373 K and shear rates between 3.3 s^{-1} and 120 s^{-1}. This paper proposes two new correlation log dynamic viscosity to the 1/T. The values of constants A, B and C and the correlation coefficients were determined by exponential and polynomial fitting of the experimental curves using Origin 6.0 software. The correlation coefficients prove a good fitting between experimental and predicted values.

REFERENCES

[1] Shay, E.G., *Biomass and Bioenergy*, **4**(4), 227, 1993.
[2] Altin, R., Cetinkaya, S., Yucesu, H.S., *Energy Conversion and Management*, **42**(5), 529, 2001.
[3] Franco, Z., Nguyen, Q.D., *Fuel*, **90**(2), 838, 2011.
[4] Ma, F.R., Hanna, M.A., *Bioresource Technology*, **70**(1), 1, 1999.
[5] Kobus, Z., Mazur, J., Nadulski, R., Guz, T., Rydzak, L., Zawiślak, K., *Przemysł Chemiczny*, **10**(94), 1728, 2015.
[6] Stanciu I., *Journal of Science and Arts*, **2**(43), 443, 2018.
[7] Schwab, A. W, Bagby, M. O, Freedman, B., *Fuel*, **66**(10), 1372, 1987.
[8] Mustafa, E. T., Van Gerpen, J. H., *Journal of the American Oil Chemists' Society*, **76**(12), 1511, 1999.
[9] Baczewski, K., Kołduński, T., *Paliwa do silników o zapłonie iskrowym*, WKiŁ, Warszawa, 2005.
[10] Stanciu I., *Journal of Science and Arts*, **1**(42), 197, 2018.
[11] Jakóbiec, J., Bocheńska, A., Ambroziak, A., *Inżynieria Rolnicza*, **15**(4), 85, 2011.
[12] Shah, P. R. Ganesh, A., *Applied Thermal Engineering*, **102**(5), 800, 2016.
[13] Tabilo-Munizaga, Gipsy, V. Barbosa-Ca´novas, Gustavo, *Journal of Food Engineering*, **67**, 147, 2005.
[14] Stanciu I., *Journal of Science and Arts*, **4**(41), 771, 2017.
[15] Valdes, F., Adolfo, B., Garcia, A., *Food Chemistry*, **98**(2), 214, 2006.
[16] Stanciu I., *Journal of Science and Arts*, **4**(17), 487, 2011.