ORIGINAL PAPER

RHEOLOGICAL BEHAVIOR OF SOYBEAN OIL

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Abstract. *This article shows the rheological behavior of soybean oil. Soybean oil were investigated using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 120* s^{-1} *and measuring viscosities from* 10^4 *to* 10^6 *mPa·s when the* HV_1 *viscosity sensor is used. The temperature ranging was from 313K to 373K and the measurements were made from 10 to 10 degrees. The accuracy of the temperature was* ± 0.1 *ºC. Measurements were done in different shear rates, during heating. For the study of rheological behavior we found three formulas that show shear shear dependence on shear stress. Equation constants a, b c and* τ_o *were determined by fitting linear and exponential.*

Keywords: *behavior, soybean, oil, viscosity, reological model.*

1. INTRODUCTION

Viscosity decreased with increasing temperature at different rates for the soybean oils. Viscosity is the fundamental rheological parameter that characterizes the fluid texture. The temperature is one of the most important parameters effecting on rheological behaviours (and obviously viscosity) because of chemical exchanging happens in foods after heating. In this work, soybean oil the rheological behaviour of has been identified in the range of 313K to 373K. The viscosities of soybean oil were investigated as a function of the shear rate and also shear stress as a function of shear rate at temperatures ranging from 313K to 373K.

Rheology is a simple analysis that is being more and applied to determine the physical behavior of solutions, suspensions and mixtures. The basic parameter, obtained in the rheological study of liquid foods, is viscosity, used to characterize the fluid texture [1, 2]. 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 key to all rheological evaluations [3,4].

The rheological models for soybean oil that describes the deviations from the Newtonian behaviour [5, 6]:

Bingham:

$$\tau = \tau_o + \eta(d\gamma/dt) \tag{1}$$

Casson:

$$\tau^{1/2} = \tau_o^{1/2} + \eta^{1/2}(d\gamma/dt)^{1/2} \tag{2}$$

Ostwald-de Waele:

$$\tau = k\,(d\gamma/dt)^n \tag{3}$$

and Herschel-Bulkley:

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$$\tau = \tau_o + k\eta(d\gamma/dt)^n \quad (4)$$

where τ is the shear stress, τ_o – yield stress, η - viscosity, $(d\gamma/dt)$ - shear rate, n – flow index and k – index of consistency.

This article proposes four new rheological models for soybean oil. Dynamic viscosity of oils was determined at temperatures and shear rates, the 373K and the 313K, respectively, 3.3 - 120 s^{-1}. The purpose of this study was to find an exponential dependence between shear rate and shear stress of soybean oil using differed equations. Equation constants a, b c and τ_o were determined by fitting exponential and linear [7-16].

2. MATERIALS AND METHODS

Soybean oil used in this work are provided by a company from Bucharest, Romania. Soybean oil were investigated using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 120 s^{-1} and measuring viscosities from 10^4 to 10^6 mPa.s when the HV_1 viscosity sensor is used. The temperature ranging was from 313K to 373K and the measurements were made from 10 to 10 degrees. The accuracy of the temperature was $\pm$0.1 ºC. Measurements were done in different shear rates, during heating.

3. RESULTS AND DISCUSSION

The rheograms for soybean oil at the specified temperatures and shear rates are shown in Figs. 1-4.

Fig. 1 shows shear shear shear shear shear shearing at temperatures ranging from 313K to 373K. The logs show a linear shear pressure shear relationship.

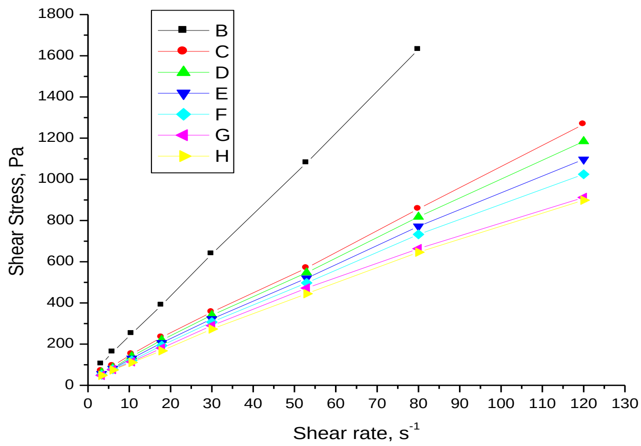

Figure 1. Rheograms for soybean oil at: ■ 313; ● – 323; ▲ – 333; ▼ – 343; ♦ - 353; ◄ – 363 and ► – 373 K.

The dependence of shear stress on the shear rate soybean oil at temperature 313K, 323K and 333K (the red curves from Figs. 2-4) was first order exponential decay as shown in figures 2,3 and 4. The exponential dependence shear stress the shear rate for soybean oil at 313K, 323K and 333K is described for equation (7).

Fig. 2 shows dependence shear stress - shear rate at 313K and exponential fitting of the first-order right-marked red.

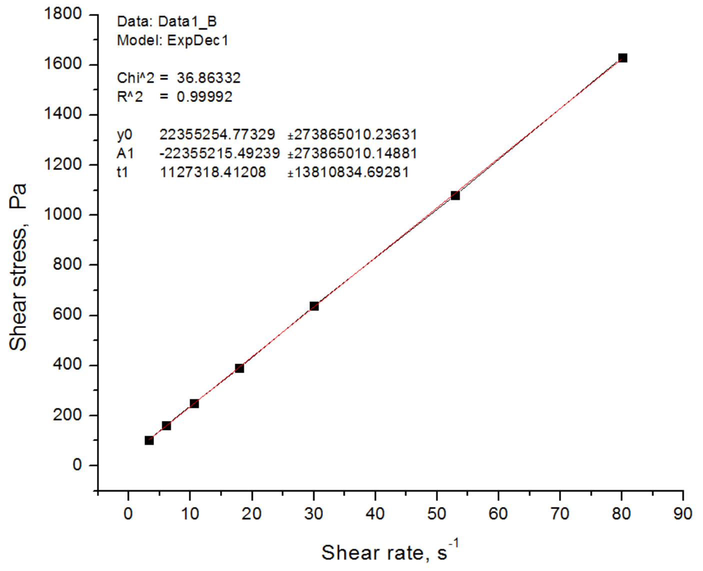

Figure 2. The correlation shear stress on the shear rate at temperature 313 for right to B and 1B represents the exponential fitting to B.

Fig. 3 shows dependence shear stress - shear rate at 323K and exponential fitting of the first-order right-marked red.

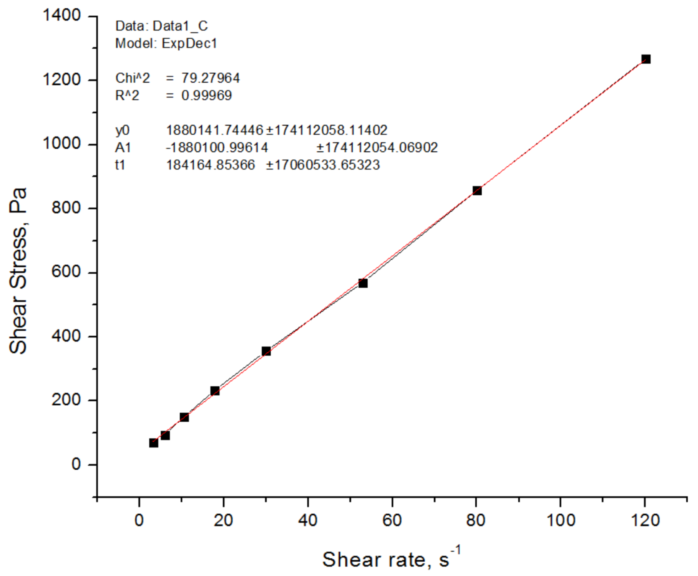

Figure 3. The correlation shear stress on the shear rate at temperature 323 for right to C and 1C represents the exponential fitting to C.

Fig. 4 shows dependence shear stress - shear rate at 333K and exponential fitting of the first-order right-marked red.

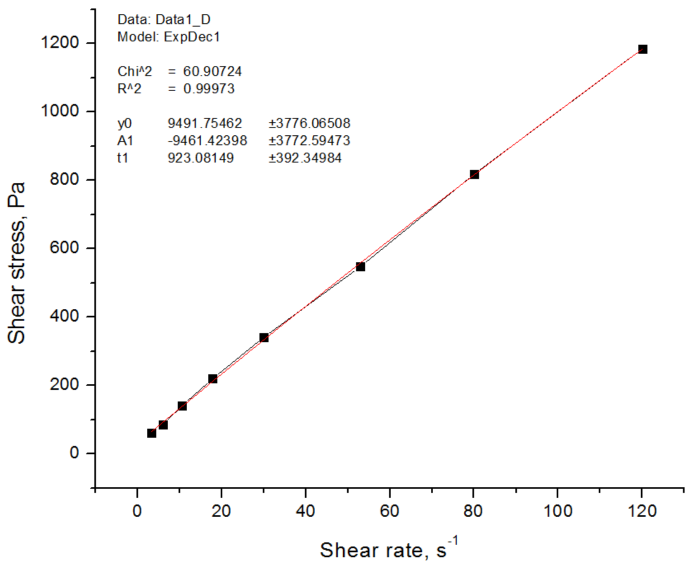

Figure 4. The correlation shear stress on the shear rate at temperature 333 for right to D and 1D represents the exponential fitting to D.

This article proposes four equations (5) - (7) shear rate dependence shear stresses checked only for soybean oil. The software Origin 6.0 was used to determine constants equation for soybean oil. In addition, the parameters a, b, c and τ_0 change with temperature.

Tables 1-3 show the constants soybean oil. As shown in Tables 1-3 the software found it exponential equations applied temperature curves of soybean oil. The root mean square error means that experimental data is spread equation. Remains the same shear rate range, where the equation was fitted other experimental data.

From the results of the regression tabulated in Tables 1-3, the lowest coefficient of determination and the highest mean square error were 0.9975 and 0.9999, respectively.

$$\tau = a + b\dot{\gamma} \quad (5)$$

$$\tau = a + b\dot{\gamma} + c\dot{\gamma}^2 \quad (6)$$

$$\tau = \tau_0 + a\exp(-\dot{\gamma}/b) \quad (7)$$

were a, b, c and τ_0 was constants soybean oil and variation with temperature.

Table 1. Correlation constants for rheological model (eq.5) at different temperature ranging from 313 K to 373K.

Temperature [K]	Value of parameters of the theoretical model described by equation (5)		R^2
	a	b	
313	19.8298	39.2877	0.9999
323	10.2058	40.7291	0.9998
333	9.6248	38.6389	0.9997
343	8.9593	38.9844	0.9994
353	8.4149	38.2984	0.9989
363	7.4829	44.6587	0.9975
373	7.3621	37.9352	0.9987

Table 2. Correlation constants for rheological model (eq.6) at different temperature ranging from 313 K to 363K

Temperature [K]	Value of parameters of the theoretical model described by equation (6)			R^2
	a	b	c	
313	42.7344	19.4858	0.0042	0.9999
323	41.0424	10.1825	1.9877E-4	0.9997
333	30.5093	10.2294	-0.0052	0.9997
343	24.9179	10.0054	-0.0089	0.9998
353	19.8339	9.7881	-0.0117	0.9999
363	18.5760	9.4227	-0.0166	0.9999
373	20.1464	8.6850	-0.0113	0.9999

Table 3. Correlation constants for rheological model (eq.7) at different temperature ranging from 313 K to 363K

Temperature [K]	Value of parameters of the theoretical model described by equation (7)			R^2
	τ_0	a	b	
313	2.2355E7	-2.2355E7	1.1273E6	0.9999
323	1.8801E6	-1.8801E6	184164.8536	0.9997
333	9491.7546	-9461.4239	923.0815	0.9997
343	5034.3435	-5009.8352	498.0696	0.9998
353	3548.8614	-3529.6679	357.3468	0.9999
363	2164.1389	-2147.1985	222.6809	0.9999
373	2875.9804	-2856.4450	325.5386	0.9999

The following conclusions can be drawn from the tables. Equation (5) can be applied at low temperatures and equations (6) and (7) at high temperatures. Correlation coefficients have values between 0.9999 and 0.9998 at low temperatures.

4. CONCLUSION

This article proposes the rheological models to describe the dependence of the shear stress of soybean oil with no additive, on the shear rate. Experimental data for one type of soybean oil were used to calculate the accuracy the proposed models. Equation constants were determined by exponential beast curves obtained at different shear rates using the program Origin 6.0. The correlation coefficients thus obtained varied between 0.9975 and 0.9999.

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