ORIGINAL PAPER

NEW MODEL THEORETICAL OF THE RHEOLOGICAL BEHAVIOR OF COCONUT OIL

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Abstract. *In this paper, we found three mathematical models that show the shear shear speed dependence on the shear stress. Experimental data for one type of coconut 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 0.9595 and 0.9999.*

Keywords: *coconut oil, rheology, behavior.*

1. INTRODUCTION

Coconut fat is one of the major ingredients for the food production in Southeast Asia and also famous in European countries in both food and non-food industries. Generally, coconut fats belong to the unique group of vegetable oils called lauric oil about 44 – 51 %. Lauric acid (CH_3 (CH_2) 10COOH) is known as small molecule fatty acid (< 14:0) which contains short or medium chain of saturated fatty acid. Other chemical compositions of coconut oil belong to myristic acid (16 – 19 %), caprylic acid (9.0 – 9.5 %), palmitic acid (8.0 – 9.5 %), oleic acid (5 – 6 %), capric acid (5 – 10 %), steric acid (3.0 – 3.5 %) and linoleic acid (1.0 – 1.5 %), respectively [1-3]. More than 90 % of fatty acids of coconut oil are saturated.

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 keys to all rheological evaluations [4]. Also according to Adolfo F. et al, research, of the two original vegetable oils studied by them, sunflower oil was found to be more sensitive to thermal treatment, undergoing greater changes in its properties, especially in viscosity, which may increase considerably [4].

The rheological models for coconut oil that describes the deviations from the Newtonian behaviour [4-6]:

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Bingham:

$$\tau = \tau_o + \eta\dot{\gamma} \tag{1}$$

Casson:

$$\tau^{1/2} = \tau_o^{1/2} + \eta^{1/2}\,\dot{\gamma}^{\,1/2} \tag{2}$$

Ostwald-de Waele:

$$\tau = k\,\dot{\gamma}^{\,n} \tag{3}$$

and Herschel-Bulkley:

$$\tau = \tau_o + k\eta\dot{\gamma}^{\,n} \tag{4}$$

where τ is the shear stress, τ_o – yield stress, η - viscosity, $\dot{\gamma}$ - shear rate, n – flow index and k – index of consistency.

This article proposes four new rheological models for coconut 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 coconut oil using differed equations. Equation constants a, b c and τ_o were determined by fitting exponential and linear [7-14].

2. MATERIALS AND METHODS

Coconut oil used in this work are provided by a company from Bucharest, Romania. Coconut 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.

3. RESULTS AND DISCUSSION

The rheograms for coconut 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.

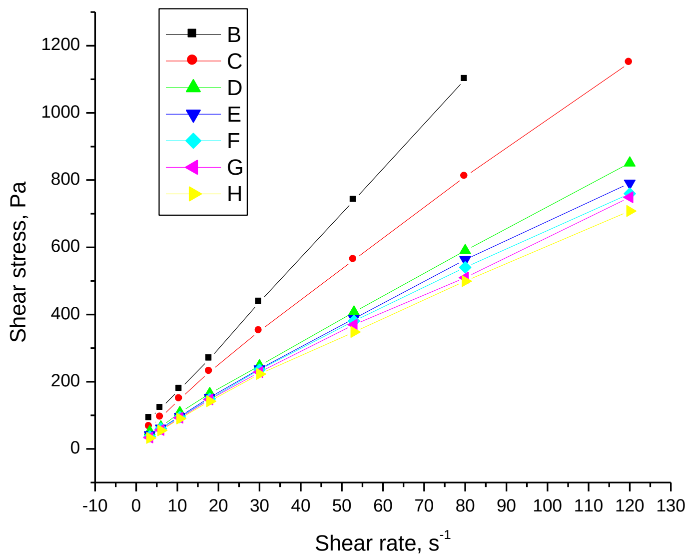

Figure 1. Rheograms for coconut oil at: ■ 313; ● – 323; ▲ – 333; ▼ – 343; ♦ - 353; ◀ – 363 and ▶ – 373 K

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

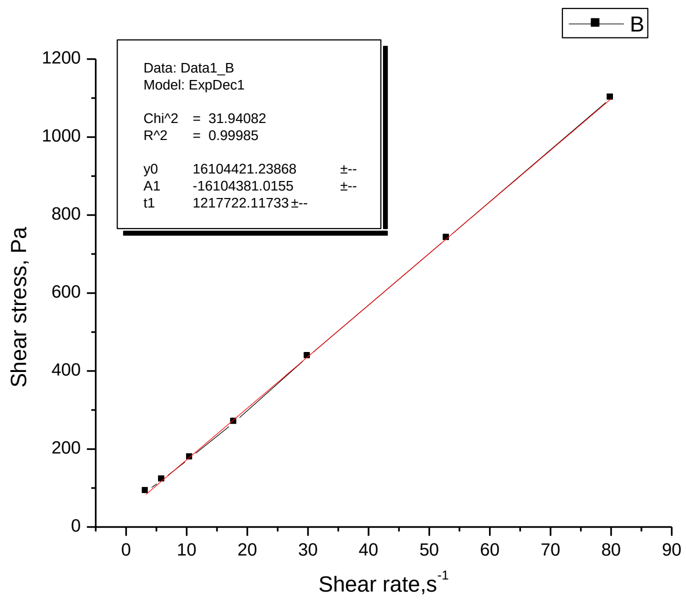

Figure 2. The correlation shear stress on the shear rate at temperature 313 for right to B and 1B represents the exponential fitting to B

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

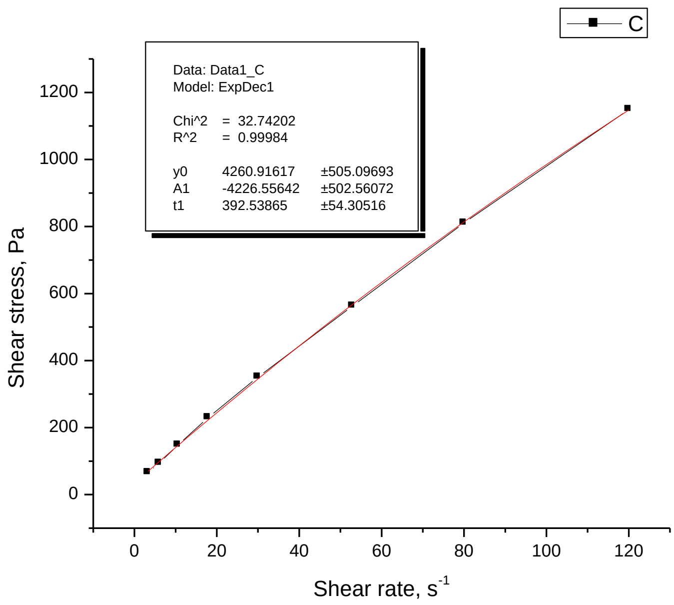

Figure 3. The correlation shear stress on the shear rate at temperature 323 for right to C and 1C represents the exponential fitting to C

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

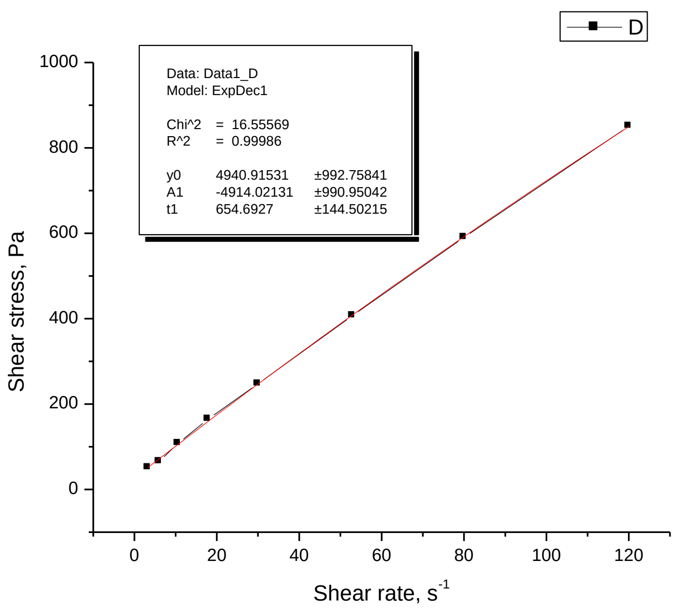

Figure 4. The correlation shear stress on the shear rate at temperature 333 for right to D and 1D represents the exponential fitting to D

This article proposes four equations (5) - (7) shear rate dependence shear stresses checked only for coconut 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 coconut oil. As shown in Tables 1-3 the software found it exponential equations applied temperature curves of coconut 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 0.9595 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	13.2248	40.2204	0.9999
323	9.3030	53.5341	0.9991
333	6.8709	35.2977	0.9996
343	6.4601	32.7716	0.9989
353	6.2037	33.5156	0.9984
363	6.0586	30.4246	0.9987
373	5.7591	31.3709	0.9985

Table 2. Correlation constants for rheological model (eq.6) at different temperature ranging from 313 K to 373K.

Temperature [K]	Value of parameters of the theoretical model described by equation (6)			R^2
	a	b	c	
313	43.5114	12.8963	0.0040	0.9999
323	35.1924	10.6671	-0.0116	0.9998
333	27.1191	7.4791	-0.0052	0.9998
343	18.5188	7.5201	-0.0090	0.9999
353	16.9179	7.4381	-0.0105	0.9998
363	18.9028	6.9155	-0.0073	0.9989
373	17.3143	6.8045	-0.0089	0.9994

Table 3. Correlation constants for rheological model (eq.7) at different temperature ranging from 313 K to 373K.

Temperature [K]	Value of parameters of the theoretical model described by equation (7)			R^2
	τ_0	a	b	
313	1.6104E7	-1.6104E7	1.2177E6	0.9999
323	4260.9162	-4226.5564	392.5387	0.9998
333	4940.9153	-4914.0213	654.6927	0.9999
343	2704.7599	-2686.8066	353.7665	0.9999
353	2194.4185	-2178.4783	288.2035	0.9999
363	748.8000	-779.0009	63.1613	0.9595
373	708	-736.1542	61.8571	0.9617

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 0.9595 at low temperatures.

4. CONCLUSION

This article proposes the rheological models to describe the dependence of the shear stress of coconut oil with no additive, on the shear rate. Experimental data for one type of coconut 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 0.9595 and 0.9999.

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