ORIGINAL PAPER

RHEOLOGICAL CHARACTERISTICS OF LUBRICATING OILS

IOANA STANCIU[1]

Manuscript received: 13.02.2020; Accepted paper: 12.04.2020;
Published online: 30.06.2020

Abstract. *The dynamic viscosity of coconut oil was measured as a function of shear rate at different temperature ranged from 40°C to 100°C. In this study, shear stress and the dynamic viscosity as a function of temperature of coconut oil decrease with increasing temperatures. Three and multi-constant formula were proposed to obtain more suitable prediction of temperature dependence of shear stress and dynamic viscosity of coconut oil. This work shows that the behavior of coconut oil at the temperature ranged from 40°C to 100°C is Newtonian behavior by fitting the model of power law.*
Keywords: *coconut oil, rheology, shear rate, viscosity.*

1. INTRODUCTION

Coconut oil contains a mixture of triglycerides which has about 50% lauric acid and 15% C6, C8 and C10 fatty acids. Coconut oil is part of the vegetable oil class being considered to be the richest source of fatty acids. Rheology is a science used to describe and evaluate the deformation and flow behavior of solid and liquid materials subjected to shear stresses or shear velocities [1, 2]. Several studies have proposed alternative equations with two or three constants to ascertain the dynamic viscosity dependence of temperature. Stanciu proposed four polynomial and exponential relations of dynamic temperature viscosity dependence for a wide range of vegetable oils [3]. Giap replaced an Arrhenius equation by derivation and applied this relation to six vegetable oils [4]. The multi-constant shapes were represented by the viscosity of the liquid as a function of temperature and were proposed by Thorpe and another by Daubert [5, 6]. Equations with three constants have been proposed by De Guzman and Vogel [7, 8]. New forms to describe the effect of temperature on viscosity were suggested by Abramovic [9].

Zhou explained the flow behavior of liquids (Newtonian or non-Newtonian) studying the shear rate as a function of temperature [10]. Chitosan dissolved in weakly acidic solutions was studied by Esam by representing the dependence of the dynamic viscosity on the shear stress and its results showed the shear stress behavior is as pseudoplastic (non-Newtonian behavior) at temperatures between 20°C and 50°C, but is shown to be predominant at low temperatures [11]. Akhtar conducted a preliminary study investigating the Newtonian or non-Newtonian behavior of the various oil samples (olive, almond, coconut, castor, sesame, cottonseed, sunflower and paraffin) and found that all. The investigated oil has a Newtonian behavior with a slight deviation in the oils of olive and coconut [12]. Giap showed that vegetable oils behaved as pseudoplastic [13]. Ashrafi studied the rheological properties for a wide range of olive oil at different temperatures [14].

[1] "Romeo Constantinescu" Agromontan Technological High School, 106400 Valeni de Munte, Romania. Romania. E-mail: istanciu75@yahoo.com.

The dynamic viscosity according to the shear rate of three commercial coconut fats highlighted the flow behavior of coconut fat and was explained according to Newton's equation. The dynamic viscosity of coconut fat at different temperatures was used to calculate the flow activation energy [15]. The plant studied twelve vegetable oils in the temperature range (35°C to 180°C) [16]. Santos evaluated the temperature dependence of the rheological behavior of unused oils (soy, sunflower, olives, rapeseed, corn, rice and soy + olive and sunflower + olive mixtures) and used vegetable cooking oils [17]. The viscosities of the three types of oil (soybean oil, sunflower oil and canola oil) were investigated as a function of shear rate and also shear stress as a function of shear rate at temperatures between 10°C and 80°C [18]. In Ștefãnescu's paper, the variation of dynamic viscosity with the shear stress for two non-additive vegetable oils of rapeseed and soybean [19]. The viscosity as a function of the temperature from 24°C to 110°C was measured by Noureddini on a number of vegetable oils (crumbs, rapeseed, maize, soy, coconut milk and lesquerella) [20, 21].
The purpose of this study is to describe the non-Newtonian behavior of coconut oil and to find a relationship of dependence on shear speed or shear stress. The equation has three characteristics that depend on the type of oil studied and on the conditions for obtaining it.

2. MATERIALS AND METHODS

Types of coconut oil used in this paper are produced from coconut crop obtained in Romania. Coconut oil was investigated with the Viscotester VT 550 viscometer with the HV_1 viscosity sensor measuring viscosities ranging from 10^4 to 10^6 mPa·s and shear rates between 3 and 120 s^{-1}. The temperature ranged between 40 and 90^{o}C and the measurements were made from 10 to 10^{o}C. The accuracy of the temperature was ± 0.1^{o}C.

3. RESULTS AND DISCUSSION

Figs. 1-7 show the dependence of the dynamic shear viscosity at all temperatures at which the coconut oil was studied. Through exponential tuning we found the parameters that depend on the chemical structure of the oil, the working conditions and the temperature. The correlation coefficients have values close to the unit.

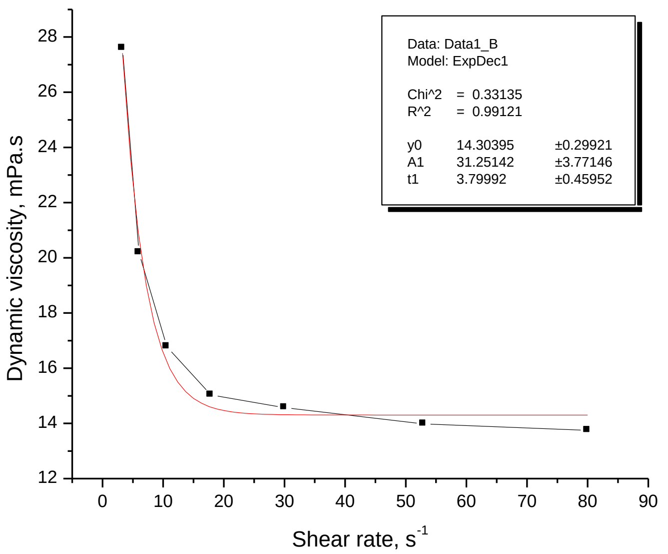

Figure 1. Dependence dynamic viscosity versus shear rate at temperature 40°C.

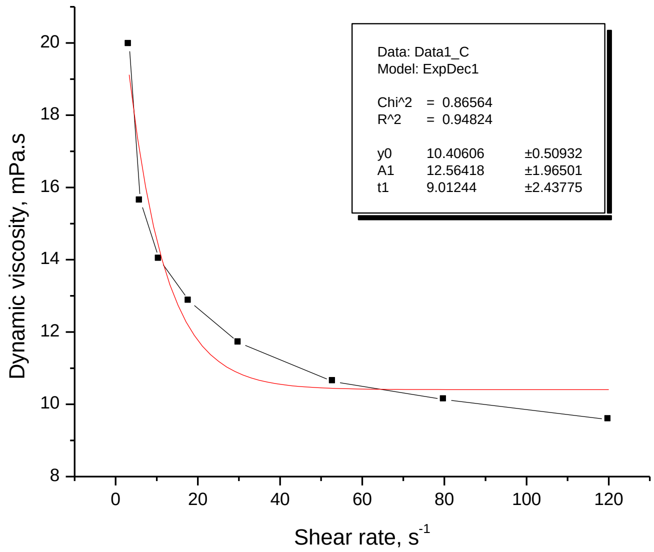

Figure 2. Dependence dynamic viscosity versus shear rate at temperature 50°C.

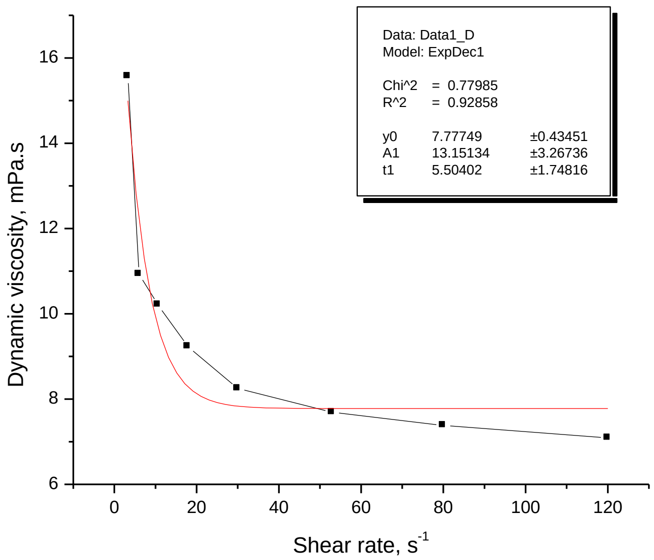

Figure 3. Dependence dynamic viscosity versus shear rate at temperature 60°C.

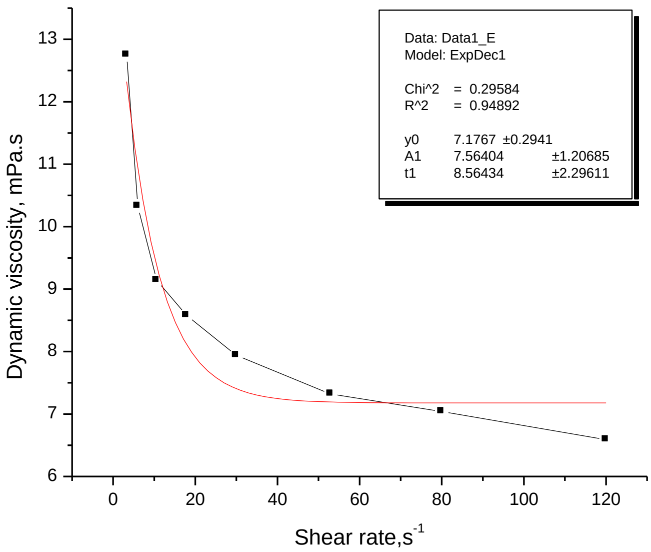

Figure 4. Dependence dynamic viscosity versus shear rate at temperature 70°C.

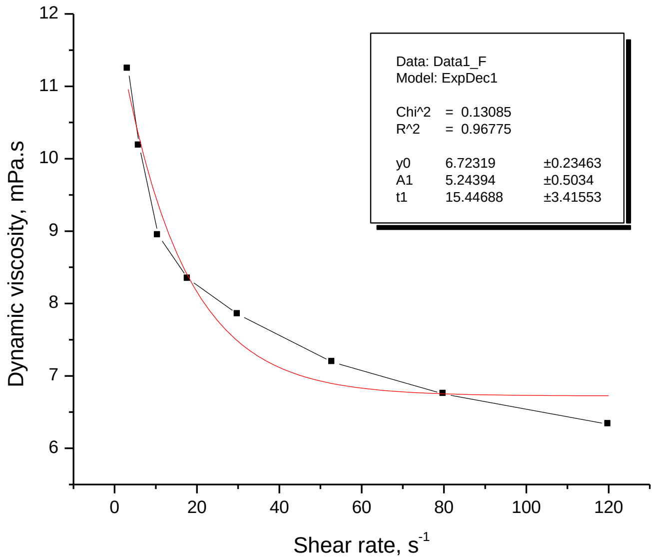

Figure 5. Dependence dynamic viscosity versus shear rate at temperature 80°C.

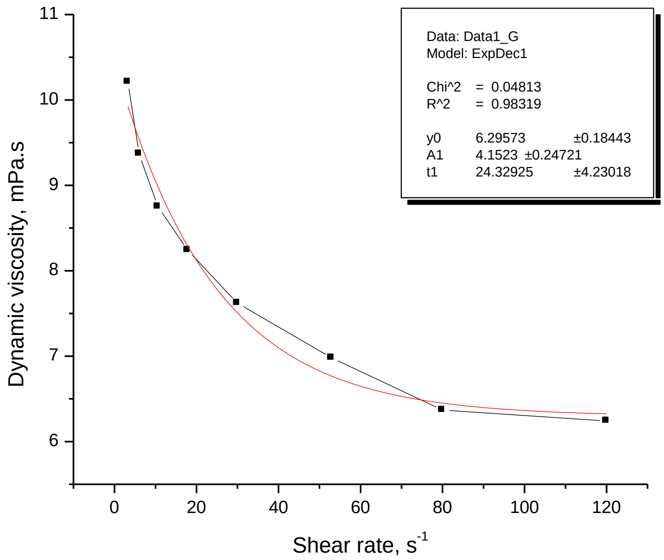

Figure 6. Dependence dynamic viscosity versus shear rate at temperature 90°C.

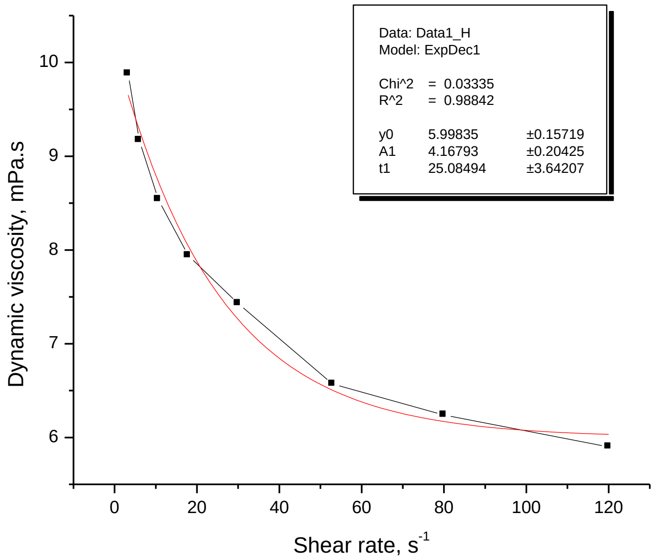

Figure 7. Dependence dynamic viscosity versus shear rate at temperature 100°C.

By exponential fit of the obtained graphs we found a dependency relation of the dynamic shear viscosity that has the form:

$$\eta = \eta_0 + A\exp\,(\dot{\gamma} / B) \qquad (1)$$

Table 1 presents the temperatures at which the coconut oil was studied, the parameter values η_0, A and B and correlation coefficients.

Table 1. The temperature, value of parameters of described by equation (1) and coefficient correlation for coconut oil

Temperature, °C	Value of parameters			Correlation coefficient, R^2
	η_0	*A*	B	
40	14.3039	31.2514	3.7999	0.9912
50	10.4061	12.5642	9.0124	0.9482
60	7.7775	13.1513	5.5040	0.9286
70	7.1767	7.5640	8.5643	0.9489
80	6.7232	5.2439	15.4469	0.9678
90	6.2957	4.1523	24.3293	0.9832
100	5.9984	4.1679	25.0849	0.9884

The values of the parameter η_0 decrease with the increase of the temperature as it happens with the parameter A. The parameter B increases with the increase of the temperature and the shear rates. The correlation coefficients have values close to the unit at all temperatures. These parameters depend on the chemical structure of the oil studied.

4. CONCLUSION

The dynamic viscosity of coconut oil was determined at temperatures between 40^0C and 100^0C and shear rates were between $3.3s^{-1}$ and $120s^{-1}$. This paper proposes one new correlation of the dynamic viscosity to the shear rate. The values of constants η_0, A and B and the correlation coefficients were determined by on exponential fitting of the experimental curves using Origin 6.0 software.

REFERENCES

[1] Barnes, H.A., Hutton, J.F., Walters, K., *An introduction to rheology*, Elsevier, USA, 1989.

[2] Steffe, J.F., *Rheological methods in food process engineering*, Freeman Press, USA, 1996.

[3] Stanciu, I., *J. Pet. Technol. Altern. Fuels*, **3**, 19, 2012.

[4] Giap, S.G.E., *J. Phys. Sci.*, **21**, 29, 2010.

[5] Thorpe, T.E., Rodger, J.W., Barnett, R.E., *Phil. Trans.*, **189**, 71, 1897.

[6] Daubert, T.E., Danner, R.P., *Physical and thermodynamic properties of pure chemicals: data compilation*, Taylor and Francis, Washington DC, 1994.

[7] De Guzman, J., *Anales Soc. Espan. Fis. Y Quim*, **11**, 353, 1913.

[8] Vogel H., *Physics*, **22**, 645, 1921.

[9] Abramovic, H., Klofutar, C., *Acta Chim Slov*, **45**, 69, 1998.
[10] Zhou, S.Q., Ni, R., Funfschilling, D., *J. Appl. Phys.*, **107**, 1, 2010.
[11] Esam, A., Elham, E.S., Mainal, A., Yahaya, A.H., *Turk. J. Chem.*, **34**, 47, 2010.
[12] Akhtar, N., Adnan, Q., Ahmad, M., Mehmood, A., Farzana, K., *J. Chem. Soc. Pak.*, **31**, 201, 2009.
[13] Giap, S.G.E., Nik, W.M.N.W., Ahmad, M.F., Amran, A., *Engin. e-Trans.*, **4**, 81, 2009.
[14] Ashrafi, N., *Effects of temperature on rheology of olive oils*, Proceedings of ASME 2009 International Mechanical Engineering Congress and Exposition, **9**, 97, 2009.
[15] Tipvarakarnkoon, T., Blochwitz, R., Senge, B., *Rheological properties and phase change behaviors of coconut fats and oils*, Proceedings of Nordic Rheology conference, **16**, 159, 2008.
[16] Fasinaa, O.O., Colleya, Z., *Int. J. Food Prop.*, **11**, 738, 2008.
[17] Santos, J.C.O., Santos, I.M.G., Souza, A.G., *J. Food Engin.*, **67**, 401, 2005.
[18] Hojjatoleslamya, M., Dehghannejada, N., Zahedia, A., Gharachorloob, M., The effect of heating on rheological behavior of vegetable edible oil, 2011.
[19] Stefanescu, I., Calomir, C., Spanu, C., *Studies concerning the vegetable oils viscosity used as biodegradable lubricant*, Proceedings of National Tribology Conference, 237, 2003.
[20] Noureddini, H., Teoh, B.C., Davis, C.L., *J. Amer. Oil Chemists' Soc.*, **69**(12), 1184, 1992.
[21] Abdelraziq, I.R., Nierat, T., *J. Mater. Sci. Eng.*, **5**, 220, 2015.
[22] Stanciu, I., *J. Sci. Arts*, **4**(17), 487, 2011.