

The Study Rheological Behavior of Sunflower Oil

Ioana Stanciu^{1*}

¹University of Bucharest, Faculty of Chemistry, Department of Physical Chemistry,
Bvd. Regina Elisabeta, no. 4-12, 030018 Bucharest, Romania

Authors' contributions

This work was done by the author IS designed the study, the statistical analysis performed, wrote the protocol, and wrote the first draft of the manuscript, managed the analyses of the study, managed the literature researches and read and approved the final manuscript.

Original Article Research

Received 2014
Accepted 2014
Published 2014

ABSTRACT

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. 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. The sunflower oil was found to be more sensitive to thermal treatment, undergoing greater changes in its properties, especially in viscosity, which may increase considerably. The viscosity of sunflower oil decreases logarithmically with temperature, but the slope representing the change is lessened. Different equations are proposed in literature to calculate the shear stress.

The sunflower oil was carefully studied in recent years because they may constitute a raw material for biodegradable lubricants getting organic. These oils are an alternative to synthetic mineral oils. This article presents rheological behavior of sunflower oil. The dynamic viscosity of sunflower oil was determined at temperatures range between 40 – 100 °C and shear rates range from 3.3 – 120 s⁻¹. The **between** 40 – 70 °C and 100 °C sunflower oil has a Bingham fluid behavior. The **between** 80 – 90 °C sunflower oil has a Casson fluid behavior.

Keywords: *rheological behavior, sunflower oil*

1. INTRODUCTION

Sunflower oil is the non-volatile oil compressed from sunflower (*Helianthus annuus*) seeds. Sunflower oil contains predominantly linoleic (48–7%), oleic (14–40%), palmitic (4–9%) and **stearic** (1–7%) [1, 2]. Oils sunflower are valuable nutrients that play an important role in health and life and they are why they have been considered as one of the essential food groups. Oils sunflower are compact source of energy and fat-soluble vitamins are involved in health. Also the role of

* Tel.: +40 0244558321;
E-mail address: istanciu75@yahoo.com.

essential fatty acids in health and body functions is proved and the body is not able to make these itself unless use vegetable oils. Oils sunflower help to improve flavor, color and texture of food and facilitate heat transfer. These materials improve the sauces rheology and texture [3-6]. According to the importance of these oils sunflower and their effects on the quality and texture of food, the factors affecting the rheological parameters of them must be considered. 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 [7]. 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 [8]. The sunflower oil was found to be more sensitive to thermal treatment, undergoing greater changes in its properties, especially in viscosity, which may increase considerably [9]. The aim of this paper is to determine the rheological behavior of sunflower oil at shear rates ranging between 3 and 120 s⁻¹ and temperatures range between 40 – 100 °C [10, 11].

2. MATERIAL AND METHODS

The sunflower oil used in this work is provided by a company from Bucharest, Romania. The fatty acid composition of the refined sunflower oil investigated is: saturated fatty acid (10%), monounsaturated fatty acid (20%) and polyunsaturated fatty acid (70%). The refined sunflower oil were investigated using a Haake VT 550 Viscometer developing shear rates ranging between 3 and 120 s⁻¹ and measuring viscosity from 10⁻⁴ to 10⁶ mPa.s when the HV₁ viscosity sensor is used. The temperature ranging was from 40 to 100°C and the measurements were made from 10 to 10 degrees. The accuracy of the temperatures was ± 0.1°C.

3. RESULTS AND DISCUSSION

The viscosity of sunflower oil decreases logarithmically with temperature, but the slope representing the change is lessened. Different equations are proposed in literature to calculate the shear stress.

Bingham:

$$\tau = \tau_0 + \eta \dot{\gamma} \quad (1)$$

Casson:

$$\tau^{1/2} = \tau_0^{1/2} + \eta^{1/2} \dot{\gamma}^{1/2} \quad (2)$$

Ostwald-de Waele:

$$\tau = k \dot{\gamma}^n \quad (3)$$

and Herschel-Bulkley:

$$\tau = \tau_0 + k \dot{\gamma}^n \quad (4)$$

where τ is the shear stress, τ_0 – yield stress, η - viscosity, $\dot{\gamma}$ - shear rate, n – flow index and k – index of consistency.

The rheograms of sunflower oil obtained from experimental data at the specified temperatures and shear rates are shown in Fig. 1 (B), 2 (C), 3 (D), 4 (E), 5 (F), 6 (G) and 7 (H) .

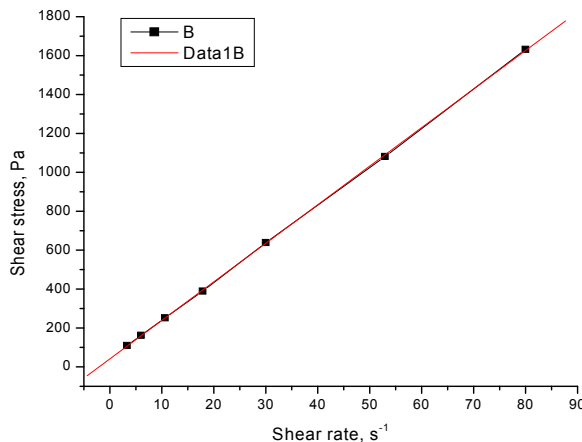
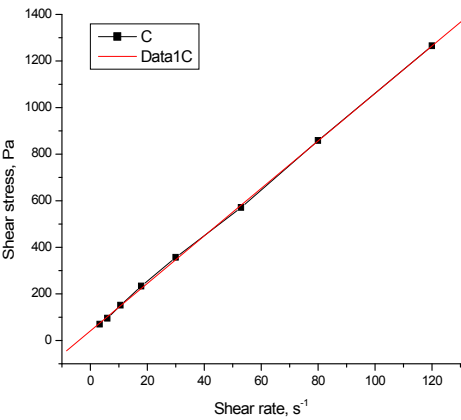
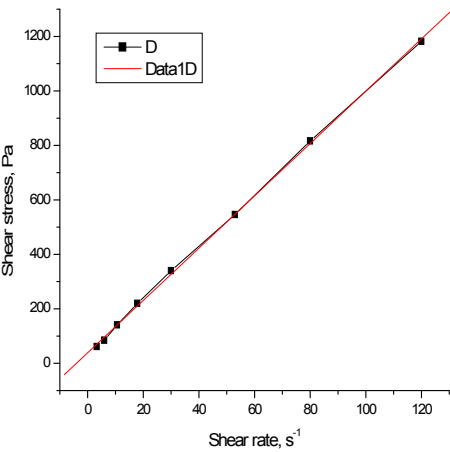


Fig. 1. Rheograms of sunflower oil at 40 °C

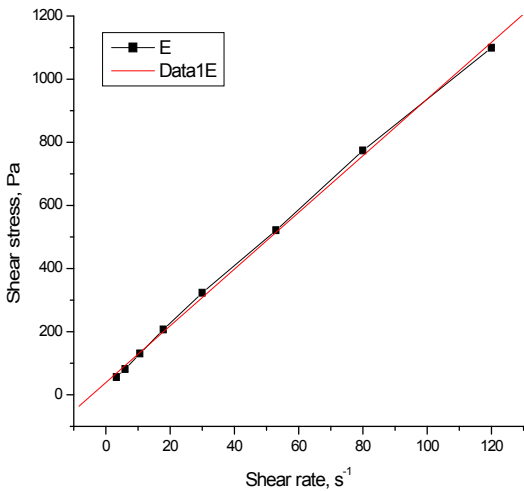
75



76
77 **Fig. 2. Rheograms of sunflower oil at 50 °C**
78



79
80 **Fig. 3. Rheograms of sunflower oil at 60 °C**
81



82
83 **Fig. 4. Rheograms of sunflower oil at 70 °C**
84

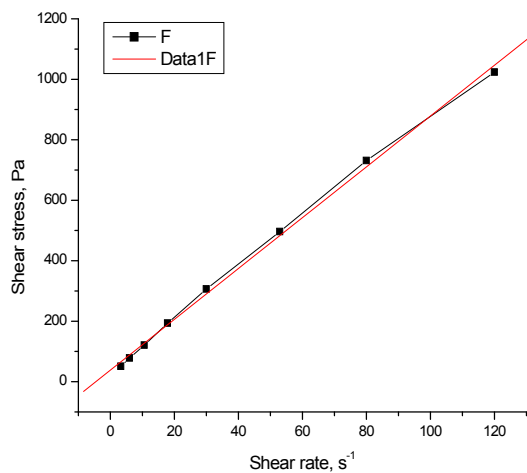


Fig. 5. Rheograms of sunflower oil at 80 °C

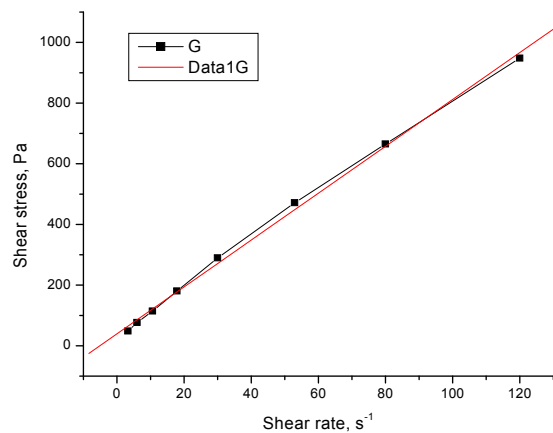


Fig. 6. Rheograms of sunflower oil at 90 °C

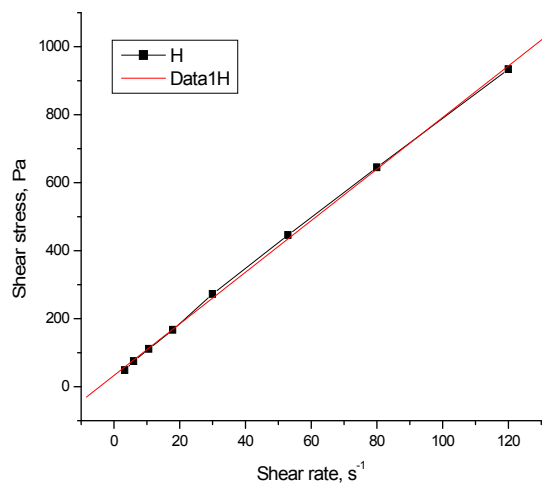


Fig.7. Rheograms of sunflower oil at 100 °C

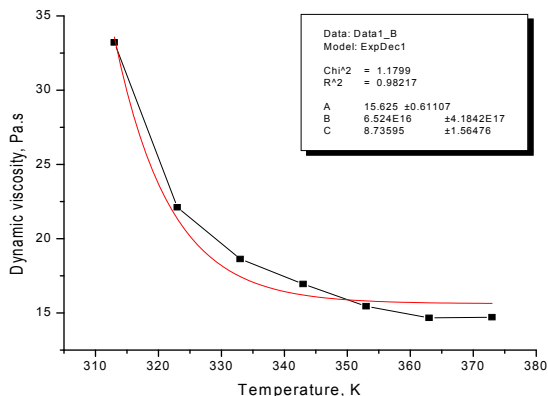


Fig. 8. Dynamic viscosity versus temperature for sunflower oil at 3.3 s⁻¹ shear rate

The dependence of dynamic viscosity on the temperature for sunflower oil at shear rate 3.3s⁻¹ and 30s⁻¹ (the black curves from **Fig. 8** and **9**) was first order exponential decay as shown in figures 8 and 9. The exponential dependence of dynamic viscosity on the temperature for sunflower oil at 3.3s⁻¹ is described for equation (5):

$$\eta = 15.625 + 6.52397E16 \exp(-T/8.73595) \quad (5)$$

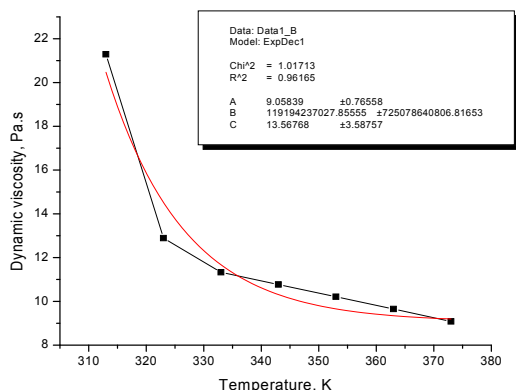


Fig. 9. Dynamic viscosity versus temperature for sunflower oil at 30 s⁻¹ shear rate

The exponential dependence of dynamic viscosity on the temperature for sunflower oil at 30s⁻¹ is described by equation (6):

$$\eta = 9.05839 + 1.19194E11 \exp(-T/13.56768) \quad (6)$$

The dynamic viscosity of sunflower oil decreases exponential with temperature increasing.

The black curves from figures 1, 2, 3, 4, 5, 6 and 7 shows that sunflower oil is described of equation Bingham (1) with correlation coefficients very close to unity (0.99995) at 40 – 70 °C and 90 °C. The between 80-90 °C sunflower oil has a Casson fluid behavior.

Correlation coefficients corresponding to shear stress calculation with Bingham, Casson, Ostwald-de Waele and respectively Herschel-Bulkey equations are listed in **Table 1**.

Table1. Correlation coefficients for models (1)-(4) for sunflower oil at temperature 40 - 100°C

Temperature, °C	Correlation coefficient, R ²			
	Model Bingham	Model Casson	Model Ostwald-de Waele	Model Herschel-Bulkley
40	0.99995	0.99768	0.99768	0.99546
50	0.99985	0.99764	0.99764	0.99430
60	0.99971	0.99840	0.99840	0.99279
70	0.99940	0.99905	0.99905	0.99345
80	0.99896	0.99935	0.99905	0.99821
90	0.99885	0.99938	0.99908	0.99367
100	0.99965	0.99858	0.99858	0.99704

At 40 °C refined sunflower oil it pseudoplastic behavior of Bingham fluid. The correlation coefficient, R² has a value of 0.99985 and dynamic viscosity is 19.81844. For the other rheological models correlation coefficients have values between 0.99546 - 0.99768. The growing studied oil temperature reaches 10 degrees viscosity 10.19663Pas and highest correlation coefficient belongs to all the Bingham model. Temperature of 60 °C correlation coefficient is the highest value and close to one, ie 0.99971. Viscosity refined sunflower oil lowers the value 9.60278Pas. Viscosity at 70 °C oil becomes 8.97932Pas and the correlation coefficient is the highest value for the Bingham model. At 80 and 90 °C refined sunflower oil behaves pseudoplastic Casson fluid. Correlation coefficients have higher values only for the equation described by the Casson model. Temperature of 100 °C refined sunflower oil has dynamic viscosity correlation coefficient 7.5876 Pas and has a value of 0.9996.

Plots of log viscosity versus 1/T for sunflower oil are represented in Fig. 10. Given the applicability for a wide variety of liquids of the Andrade equation (7) this was used for analyzing the variation of dynamic viscosity with temperature [10]:

$$\eta = A \cdot 10^{B/T} \tag{7}$$

where: η – dynamic viscosity (Pa·s), T temperature (Kelvin degree), A and B are constants for a given fluid. The constants A and B in accordance to Andrade equation were also determined for sunflower oil was (Table 2):

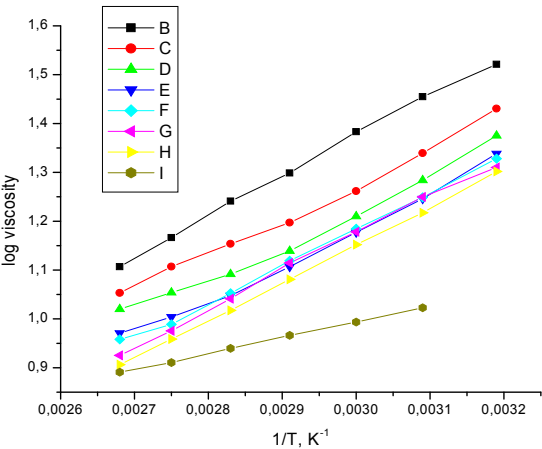


Fig. 10. Plot of log viscosity as a function of 1/T sunflower oil at: B – 3.3s⁻¹, C – 6s⁻¹, D – 10.6s⁻¹, E – 17.87s⁻¹, F – 30s⁻¹, G – 52.95s⁻¹, H – 80s⁻¹ and I – 120s⁻¹

Table 2. Constants A and B for equation Andrade for sunflower oil and shear rate

Shear rate, s^{-1}	log A	B
3.3	-1.0943	823.0914
6	-0.8809	719.2359
10.6	-0.8635	695.2737
17.87	-0.9898	724.6267
30	-1.0409	741.6243
52.95	-1.1407	771.6052
80	-1.1677	773.0162
120	0.0209	324.3608

4. CONCLUSION

The dynamic viscosity of sunflower oil was determined for temperature range between 313 – 373 K and shear rates ranging from 3.3 – 120 s^{-1} . The dynamic viscosity of sunflower oil decreases exponential with temperature increasing. The between 40 – 70 °C and 90 °C sunflower oil has a Bingham fluid behavior. The between 80 - 90 °C sunflower oil has a Casson fluid behavior.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Santos JCO, Santos IMG, Souza AG. Effect of heating and cooling on rheological parameters of edible vegetable oils. *Journal of food Engineering*. 2005;67(4):401-405.
2. Wan Nik WB, Ani FN, Masjuki HH, Eng Giap SG. Rheology of bio-edible oils according to several rheological models and its potential as hydraulic fluid. *Industrial Crops and Products*. 2005;22(3):249-255.
3. Bower C, Gallegos C, Mackley MR, Madieto JM. The rheological and microstructural characterisation of the non-linear flow behaviour of concentrated oil-in-water emulsions. *Rheologica acta*. 1999;38(2):145-159.
4. Rouilly A, Orliac O, Silvestre F, Rigal L. New natural injection-moldable composite material from sunflower oil cake. *Bioresource technology*. 2006;97(4):553-561.
5. Orliac O, Silvestre F, Rouilly A, Rigal L. Rheological studies, production, and characterization of injection-molded plastics from sunflower protein isolate. *Industrial & engineering chemistry research*. 2003;42(8):1674-1680.
6. Guerrero A, Partal P, Gallegos C. Linear viscoelastic properties of sucrose ester-stabilized oil-in-water emulsions. *Journal of Rheology*. 1998;42:1375.
7. Fasina OO, Hallman H, Craig-Schmidt M, Clements C. Predicting temperature-dependence viscosity of vegetable oils from fatty acid composition. *Journal of the American Oil Chemists' Society*. 2006;83(10):899-903.
8. Hayati IN, Che Man YB, Tan CP, Aini IN. Stability and rheology of concentrated O/W emulsions based on soybean oil/palm kernel olein blends. *Food Research International*. 2007;40(8):1051-1061.
9. Alpaslan M, Hayta M. Rheological and sensory properties of pekmez (grape molasses)/tahin (sesame paste) blends. *Journal of Food Engineering*. 2002;54(1):89-93.
10. Akhtar N, Adnan Q, Ahmad M, Mehmood A, Farzana K. Rheological studies and characterization of different oils. *Journal of the chemical society of pakistan*. 2009;31(2):201-206.
11. Lee SK, Anema S, Klostermeyer H. The influence of moisture content on the rheological properties of processed cheese spreads. *International journal of food science & technology*. 2004;39(7):763-771.