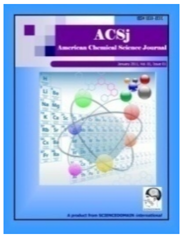

American Chemical Science Journal
4(4): 537-545, 2014

SCIENCEDOMAIN *international*
www.sciencedomain.org

Application of New Models in Rheological Behavior Study Sunflower Oil

Ioana Stanciu[1*]

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

Author's contribution

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 Research Article

Received 28th December 2013
Accepted 29th January 2014
Published 17th March 2014

ABSTRACT

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 stearitic (1–7%). In general, viscosity measures the resistance of a liquid to flow. From a molecular point of view, viscosity is an indirect measurement of the internal friction between the molecules that constitute the fluid and which oppose liquid movement. Therefore, viscosity must have significant correlations with structural parameters of the fluid molecules.
The sunflower 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 10^6mPa.s when the HV_1 viscosity sensor is used. In this article we presented rheological models to study the behavior of sunflower oil. The constants A, B, and C were determined by Origin 6.0 software by fitting exponential curves obtained from experimental data. The one proposed relationship gives correlation coefficients close to one. For three-dimensional representation of the shear rate by shear stress at different temperatures we used Origin 6.0 software. From the diagram it is observed that at low temperatures sunflower oil has the highest shear stress and therefore dynamic viscosity highest at high temperatures sunflower oil has the lowest shear stresses and therefore dynamic viscosity lowest.

**Corresponding author: Email: istanciu75@yahoo.com;*

Keywords: Models rheological; sunflower oil; behavior.

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 stearitic (1–7%) [1-4].

In general, viscosity measures the resistance of a liquid to flow. From a molecular point of view, viscosity is an indirect measurement of the internal friction between the molecules that constitute the fluid and which oppose liquid movement. Therefore, viscosity must have significant correlations with structural parameters of the fluid molecules [5-9].

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 [10-14].

Bingham:

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

Casson:

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

Ostwald-de Waele:

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

and Herschel-Bulkley:

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

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 new models in rheological behavior study sunflower oil.

2. MATERIALS AND METHODS

The sunflower oil used in this work is provided by a company from Bucharest, Romania. The sunflower 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 10^6mPa.s when the HV_1 viscosity sensor is used. The temperature ranging was from 40 to 100ºC and the measurements were made from 10 to 10 degrees. The accuracy of the temperatures was ± 0.1°C.

3. RESULTS AND DISCUSSION

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). Parameter values are given inside the Fig. 1, the correlation coefficient is 0.99991 at 40ºC for sunflower oil. The exponential dependence of shear stress on the shear rate for sunflower oil at 40º C is described for equation (5):

$$\tau=(-2.12556E7)+2.12556E7\exp[(-\dot{\gamma}/(-1.07257E6)] \quad (5)$$

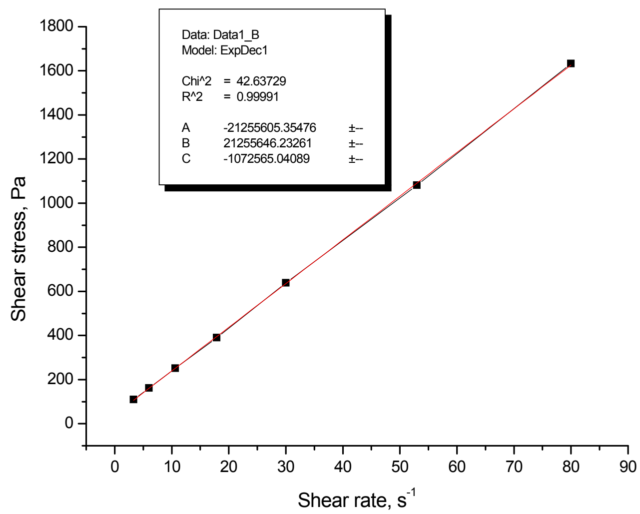

Fig. 1. Rheograms of sunflower oil at 40ºC and 1B represent the fitting exponential to B

The values are: A = -2.12556E7, B = 2.12556E7 and C = -1.07257E6. At a temperature 40^0 C measurement errors were 42.63729.

The sunflower oil shows an exponential shear stress with shear rate as shown in Fig. 2. Parameter values are given inside the figure, the correlation coefficient is 0.9997 at 50^0 C sunflower oil. The exponential dependence of shear stress on the shear rate for sunflower oil at 50^0 C is described for equation (6):

$$\tau = 88606.96966-88566.71219\exp(-\dot{\gamma}/8627.17304) \quad (6)$$

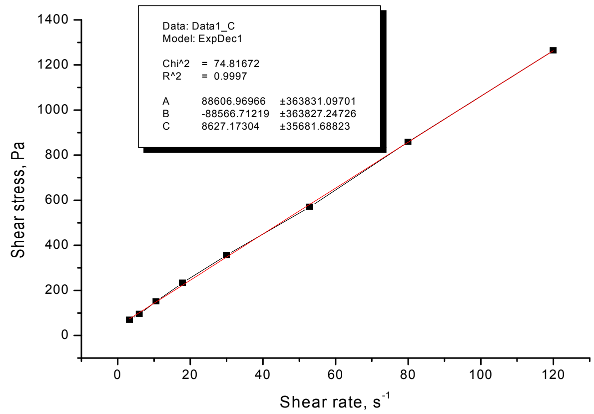

Fig. 2. Rheograms of sunflower oil at 50ºC and 1C represent the fitting exponential to C

At temperature 50ºC the parameter A increased by -21344206.96966 units, the parameter B has decreased by 21167033.2879 units and the parameter C increased by -1081127.17304 units. Increasing the temperature by 10ºC leads to a higher error 32.17943 units.

The sunflower oil shows an exponential shear stress with shear rate as shown in Fig. 3. Parameter values are given inside the figure, the correlation coefficient is 0.99972 at 60^0 C sunflower oil. The exponential dependence of shear stress on the shear rate for sunflower oil at 60ºC is described for equation (7):

$$\tau = 9459.11533 - 9428.57558 \exp(-\dot{\gamma}/921.91261) \quad (7)$$

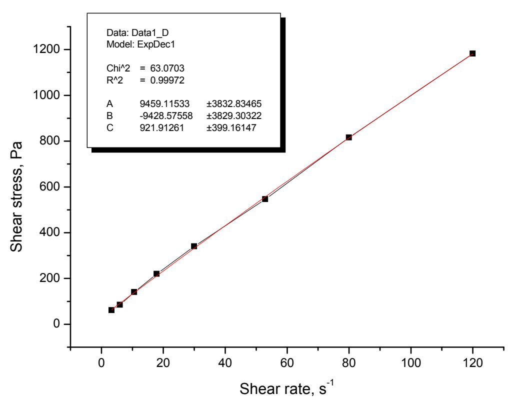

Fig. 3. Rheograms of sunflower oil at 60ºC and 1D represent the fitting exponential to D

Increasing the temperature by 20ºC the parameter A increased by -21265059.11533 units, the parameter B has decreased by 21246171.42442 units and the parameter C increased by -1073491.91261 units. At 60ºC measurement error increases with 20.4326 units.

The sunflower oil shows an exponential shear stress with shear rate as shown in Fig. 4. Parameter values are given inside the figure, the correlation coefficient is 0.99981 at 70ºC sunflower oil. The exponential dependence of shear stress on the shear rate for sunflower oil at 70ºC is described for equation (8):

$$\tau = 5055.54009 - 5031.03084 \exp(-\dot{\gamma}/499.19029) \quad (8)$$

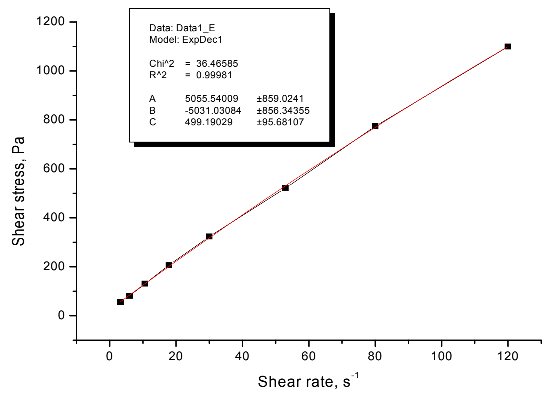

Fig. 4. Rheograms of sunflower oil at 70ºC and 1E represent the fitting exponential to E

Increasing the temperature by 30ºC the parameter A increased by -21260655.54009 units, the parameter B has decreased by 21250568.96916 units and the parameter C increased by -1073069.19029 units. At 70º C measurement error decreases with 5.97879 units.

The sunflower oil shows an exponential shear stress with shear rate as shown in Fig. 5. Parameter values are given inside the figure, the correlation coefficient is 0.99986 at 80ºC sunflower oil. The exponential dependence of shear stress on the shear rate for sunflower oil at 80ºC is described for equation (9):

$$\tau = 3581.15799 - 3561.71378 \exp(-\dot{\gamma}/361.87488) \quad (9)$$

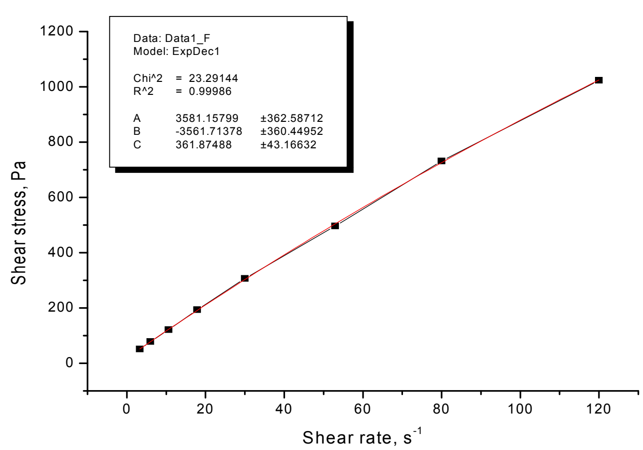

Fig. 5. Rheograms of sunflower oil at 80^{0}C and 1F represent the fitting exponential to F

Increasing the temperature by 40º C the parameter A increased by -21259181.15799 units, the parameter B has decreased by 21252038.28622 units and the parameter C increased by -1072931.87488 units. At 80º C measurement error decreases with 19.34585 units.

The sunflower oil shows an exponential shear stress with shear rate as shown in Fig. 6. Parameter values are given inside the figure, the correlation coefficient is 0.99983 at 90ºC sunflower oil. The exponential dependence of shear stress on the shear rate for sunflower oil at 90º C is described for equation (10):

$$\tau=3156.74537-3135.52088 \exp(-\dot{\gamma}/343.68052) \quad (10)$$

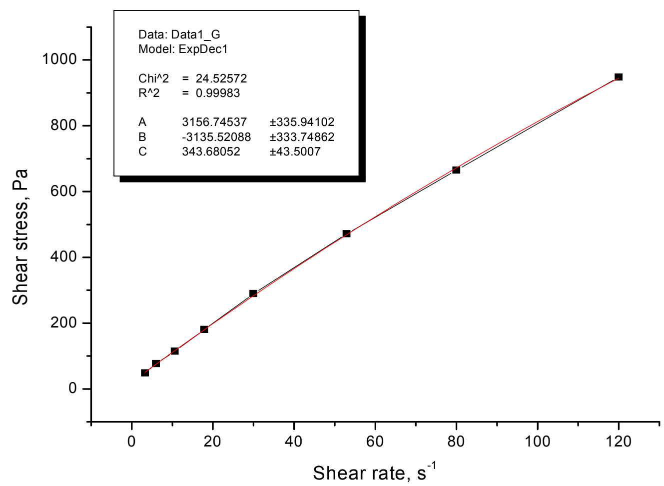

Fig. 6. Rheograms of sunflower oil at 90ºC and 1G represent the fitting exponential to G

Increasing the temperature by 50º C the parameter A increased by -21258756.74537 units, the parameter B has decreased by 21252464.47912 units and the parameter C increased by -1072913.68052 units. At 90º C measurement error decreases with 18.11157 units.

The sunflower oil shows an exponential shear stress with shear rate as shown in Fig. 7. Parameter values are given inside the figure, the correlation coefficient is 0.99992 at 100ºC sunflower oil. The exponential dependence of shear stress on the shear rate for sunflower oil at 100º C is described for equation (11):

$$\tau= 5337.67775- 5314.09081 \exp(-\dot{\gamma}/639.8184) \quad (11)$$

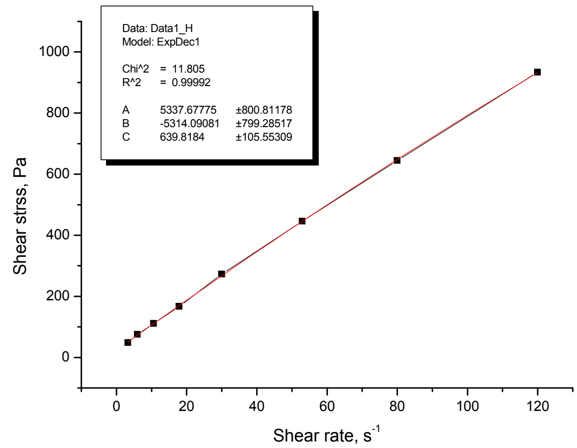

Fig. 7. Rheograms of sunflower oil at 100^{0}C and 1H represent the fitting exponential to H

Increasing the temperature by 60ºC the parameter A increased by -21260937.67775 units, the parameter B has decreased by 21250285.90919 units and the parameter C increased by -1073209.8184 units. At 100ºC measurement error decreases with 30.83229 units.

Fig. 8 shows rheograms sunflower oil in three-dimensional presentation. For three-dimensional representation of the shear rate by shear stress at different temperatures we used Origin 6.0 software. From this diagram is can observe that with the temperature increasing the shear stress of sunflower oil decrease at each constant shear rate. This diagram shows that the viscosity of sunflower oil is correlated with the shear rate at a given temperature and negatively correlated to the temperature at constant shear rate. If sunflower oil is used as raw material in industry, high temperatures will not affect the rheological characteristics at 80º C and 90ºC.

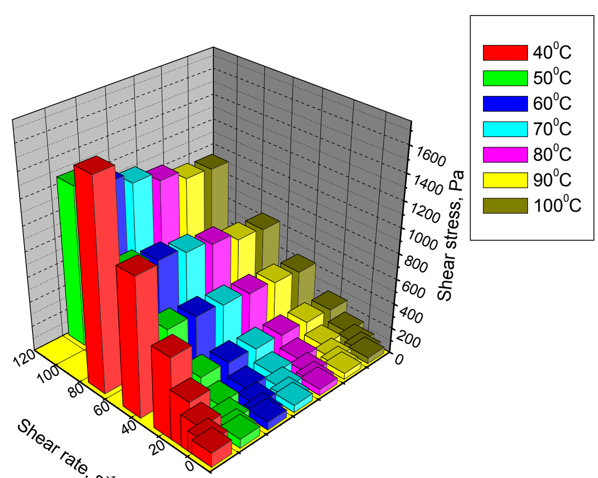

Fig. 8. Rheograms for sunflower oil at all temperatures

4. CONCLUSION

The dynamic viscosity of sunflower oil was determined at temperatures between 313 and 373K and shear between $3.3s^{-1}$ and $120s^{-1}$. This article proposes new models in rheological behavior study sunflower oil. The values of constants A, B and C and the correlation coefficients were determined by exponential fitting of the experimental curves using Origin 6.0 software.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Razi H, Asad MT. Evaluation of variation of agronomic traits and water stress tolerant in sunflower conditions. Agricultural and Natural Resources Sciences. 1998;2:31-43.
2. Abdel-Motagally FMF, Osman EA. Effect of nitrogen and potassium fertilization combination of productivity of two sunflower cultivars under east of El-ewinate conditions. American-Eurasian Journal of Agricultural & Environmental Science. 2010;8(4):397-401.
3. Hemphill T, Wellington C, Pilehvari A. Yield-power law model more accurately predicts mud rheology. Oil and Gas Journal(United States). 1993;91(34).
4. Holdsworth SD. Applicability of rheological models to the interpretation of flow and processing behaviour of fluid food products. Journal of Texture Studies. 1971;2(4):393-418.
5. Toro-Vazquez JF, Infante-Guerrero R. Regressional models that describe oil absolute viscosity. Journal of the American Oil Chemists Society. 1993;70(11):1115-1119.
6. Bower C, Gallegos C, Mackey MR, Madiedo 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.
7. Wan Nik WS, Senin SB, Eng Giap SG. Application of modified power law and Arrhenius relationship in studying rheological behavior of bio-oils. Materials science forum. 2006;517:147-152.
8. Sunny G, Eng Giap SG, Azira A. Dynamic Viscosity As A Function Of Shear Rate: The Comparison Of Established Rheological Models With The Newly Derived Rheological Model For The Estimation Of Zero–And Infinite–Shear Rate Viscosity Of Vegetable Oils. Jurnal Teknologi. 2012;54(1):111-120.
9. Chiralt A, Ferragut V, Salazar JA. Rheological Characterization of Low-calorie Milk-based Salad Dressings. Journal of food science. 1992;57(1): 200-202.
10. Fasina OO, Colley Z. Viscosity and specific heat of vegetable oils as a function of temperature: 35 C to 180 C. International Journal of Food Properties.2008;11(4):738-746.
11. Wan NWB, 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.
12. 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.

13. 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.
14. Silletti E, Vingerhoeds MH, Van Aken GA, Norde W. Rheological behavior of food emulsions mixed with saliva: effect of oil content, salivary protein content, and saliva type. Food Biophysics. 2008;3(3):318-328.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=424&id=16&aid=4007