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A study of rheological behavior for refined rapeseed oil

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Abstract The refined rapeseed oil were 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 refined rapeseed oil. The dynamic viscosity of refined rapeseed oil was determined at temperatures range between 313 – 363 K and shear rates range from 3.3 – 120 s^{-1}. For temperature ranging between 313 – 363 K refined rapeseed oil has a Bingham fluid behavior.

Keywords: rheological behaviour, refined rapeseed oil

1. Introduction

As the uppermost herbaceous edible oil crop in Romania, rape (*Brassica Napus*) has been cultivated for probably hundreds of years. The rapeseed oil extracted from the rape seed top-quality edible oil, which contains rich acids, fast-soluble vitamins, phospholipids and pigments but lacks cholesterol [1]. The color of oil is deep yellow. The characteristic of great viscosity, reduced saponification value among semi-drying oils and high-content of acid can be used to distinguish rapeseed oil from other vegetable oils [2, 3].

Besides the direct application of edibility, rapeseed oil is also an important raw industrial material [4] and widely applied to industries of machinery, rubber, chemical, plastic, painting, textile, soap, pharmaceutical and bio-diesel [5-7].

The aim of this paper is to determine the rheological behaviour of refined rapeseed oil at shear rates ranging between 3 and 120 s^{-1} and temperatures range between 313 – 363 K [8].

2. Experimental

The rheological behaviour of refined rapeseed oil was determined using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 1312 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 313 to 363K and the measurements were made from 10 to 10 degrees.

The accuracy of the temperature measurement was ± 0.1°C.

3. Results and Discussions

Viscosity is a measure of the “shear strength” of a thin layer of oil [9] or, in other words, of the property the oil has to develop and maintain a certain amount of shearing stress dependent on flow, and than to offer continued resistance to flow. The viscosity of refined rapeseed 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:

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

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:

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

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

The rheograms of refined rapeseed oil obtained from experimental data at the specified temperatures and shear rates are shown in **Fig. 1** (B)**, 2** (C)**, 3** (B)**, 4** (B)**, 5** (B) and **6** (B).

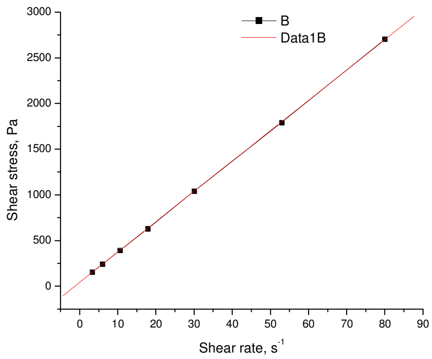

Fig.1. Rheograms of refined rapeseed oil at 313 K

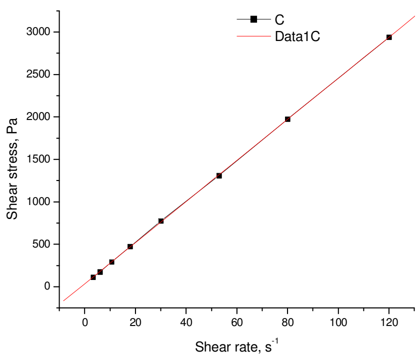

Fig.2. Rheograms of refined rapeseed oil at 323 K

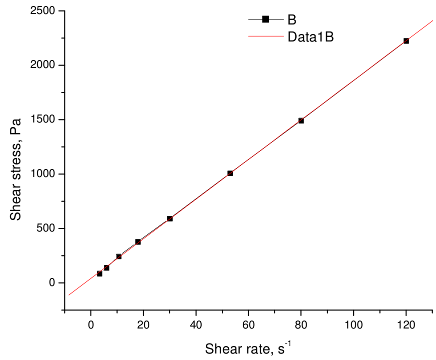

Fig. 3. Rheograms of of refined rapeseed oil at 333 K

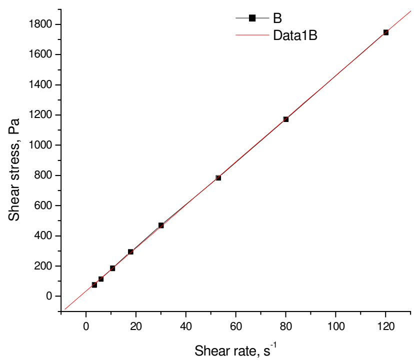

Fig. 4. Rheograms of of refined rapeseed oil at 343 K

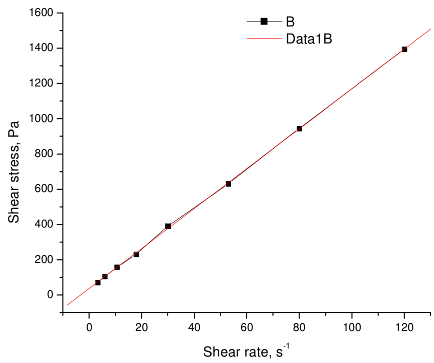

Fig. 5. Rheograms of of refined rapeseed oil at 353 K

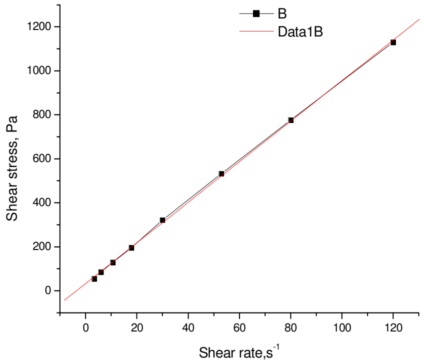

Fig.6. Rheograms of of refined rapeseed oil at 363 K

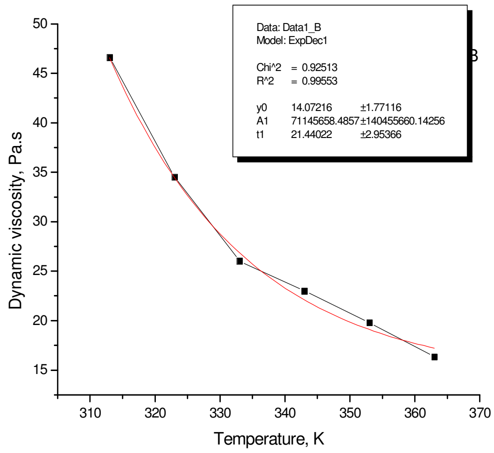

Fig. 7. Dynamic viscosity versus temperature for refined rapeseed oil at 3.3 s^{-1} shear rate

The dependence of dynamic viscosity on the temperature for refined rapeseed oil at shear rate 3.3s^{-1} and 30s^{-1} (the black curves from **Fig. 7** and **8**) was first order exponential decay as shown in figures 7 and 8. The exponential dependence of dynamic viscosity on the temperature for refined rapeseed oil at 3.3s^{-1} is described for equation (5):

$$\eta = 14.0721 + 71145658.48\exp(-T/21.4402) \qquad (5)$$

The exponential dependence of dynamic viscosity on the temperature for refined rapeseed oil at 30s^{-1} is described for equation (6):

$$\eta = 10.6029 + 1157927813.31\exp(-T/17.73127) \qquad (6)$$

The dynamic viscosity of refined rapeseed oil decreases exponential with temperature increasing. The black curves from figures 1, 2, 3, 4, 5 and 6 show that refined rapeseed oil is described of equation Bingham (1) with correlation coefficients very close to unity (0.9999) at 313 – 363 K.

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

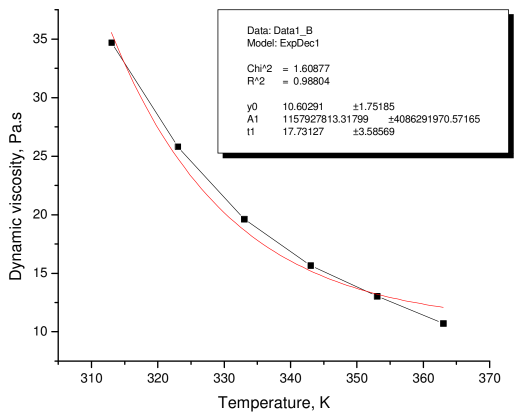

Fig. 8. Dynamic viscosity versus temperature for refined rapeseed oil at 30 s^{-1} shear rate

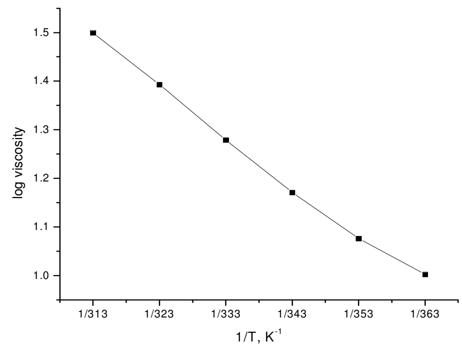

Fig. 9. Plot of log viscosity as a function of 1/T for refined rapeseed oil

Table1. Correlation coefficients for models (1)-(4) for refined rapeseed oil at temperature 40 - 90ºC

Correlation coefficient, R^2				
Temperature, K	Model Bingham	Model Casson	Model Ostwald-de Waele	Model Herschel-Bulkley
313	0.9999	0.9990	0.9990	0.9992
323	0.9999	0.9992	0.9992	0.9993
333	0.9999	0.9997	0.9997	0.9997
343	0.9999	0.9990	0.9990	0.9990
353	0.9999	0.9972	0.9971	0.9972
363	0.9998	0.9989	0.9990	0.9989

Plots of log viscosity versus 1/T for refined rapeseed oil are represented in **Fig. 9.** 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]:

$$\eta = A \cdot 10^{B/T} \quad (7)$$

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 refined rapeseed oil was: log A = -0.09826 and B = 1.60496.

4. Conclusions

The dynamic viscosity of refined rapeseed oil was determined for temperature range between 313 – 363 K and shear rates ranging from 3.3 – 120 s^{-1}. The dynamic viscosity of refined rapeseed oil decreases exponential with temperature increasing. Between 313 – 363 K refined rapeseed oil has a Bingham fluid behavior.

5. References

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