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Theoretical rheological models for olive oil

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Abstract. This paper proposes new rheological models for olive oil. The purpose of this study was to find an exponential dependence between temperature and dynamic viscosity of olive oil, using one equation. Equation constants $\ln\eta_0$, A_1 and t_1 were determined by fitting exponential. The olive oil have 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.
Olive oil dynamic viscosity decreases with increasing temperature at constant shear rate. Plotting the ln dynamic viscosity depending on temperature shows an exponential decline.
Keywords. Rheology, oilve oil, theoretical

Introduction

Rheology is the science of deformation when used for food that paves the way for a better understanding of structural changes during the processing of these products. An important rheological parameter needed in selecting pumps and pipes for handling vegetable oils is viscosity. Despite the abundance of studies on the microstructure of olive oils, their rheology has been rarely researched. Among the very few articles however, rather historically, studies on the rheology of liquid foods by Rao [1, 13] should be mentioned. Some physical properties of edible oils, such as the dynamic viscosity of triglycerides [2,13] as well as the rheology of vegetable oils [3,13] are also reported.

Research on edible oils also covers more detailed topics such as elasticity and extensive viscosity [4,13]. Viscosity is a measure of the resistance of fluid layers to slip when subjected to shear stress. More microscopically speaking, therefore, is related to the size and orientation of molecules. It is well known that the viscosity of vegetable oils increases with the length of the chain of fatty acid triglycerides and decreases with unsaturation, in other words, increases with hydrogenation [5,13]. Changes in rheological properties are also attributed to physico-chemical changes in edible oils. Therefore, the change in the viscosity of the oils may be indicative of a possible degradation, which is the subject of this study. Viscosity can also be a determining parameter for heat transfer [6,13].

In addition to the benefits of studying the rheology of the final product, the oil extraction process can also be better explored using rheological parameters of olive oils. For example, kneading, a slow and continuous kneading process of olive paste can be optimized on based on the time and temperature of the kneading [7,13].

This can be rheologically monitored the behavior of pasta. Further, other studies report on the effects of heating and cooling a number of edible oils [8,13]. A study to classify the rheology of olive oils based on frying temperature is however not yet found. Today, for several reasons, such as health concerns,

especially coronary heart disease, more attention is being paid to the type of oil used for frying purposes. A better understanding of rheology can be useful changes based on temperature variations deep frying optimization as one of the most common operations in food preparation. Compared to many regular cooking oils, extra virgin olive oil due to the low level of fatty acids is claimed to be a suitable choice for (repeated) frying. This is addressed in the present study as the current effect of temperature on rheological parameters can provide an insight into the microstructure changes and therefore their adequacy.
oil for frying. Among the rheological data, its viscosity and sensitivity to temperature and shear rate can be indicated microstructural changes. In addition, it is known that viscosity values are highly correlated with polar compounds. Therefore, viscosity measurements are good oil degradation index [9,13]. It is important to note that the viscosity of oils, especially olive oils, increases by at least a factor of two with the number of times frying at 170 ° C [9,13]. As shown in the present study, the viscosity increases beyond this temperature significantly in the order of magnitudes.
In general, edible oils are classified as Newtonian Liquids [10,13], so that their viscosities remain unchanged regardless of the shear rate.

The increase in temperature, however, decreases the viscosity between these oils exponentially. Also, when mixed with other additives, to make salad dressings for example, the mixture tends to distance itself further from a Newtonian fluid. In this regard, some rheological parameters of the mixtures of olive oil and lemon juice were measured to establish its stabilization [11,13] and also the rheology of a white was investigated the sauce model [12,13]. The question presented here is how temperature affects the rheology of olive oils and therefore whether different types of olive oils are suitable for frying. This study aims to obtain rheological variations in the parameters of olive oils depending on temperature and shear rate. This, in addition to applications in the food processing industry, can also provide information about physico-chemical and sensory changes in the oil during the process.

The more important of these is the Andrade equation (1). Andrade [14] equations are modified versions of equations (2) and (3) [15-18]:

$$\eta = A \cdot 10B/T \tag{1}$$

$$ln\eta = A + B/T + C/T^2 \tag{2}$$

and

$$ln\ \eta = A + B/T + CT \tag{3}$$

where T is the temperature absolute and A, B and C in the equations (1) to (3) are correlation constants.

This paper proposes new rheological models for olive oil. The purpose of this study was to find an exponential dependence between temperature and dynamic viscosity of olive oil, using one equation.

Experimental details

Types of oilve oil used in this paper are produced in Romania. The oilve oil have 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 HV1 viscosity sensor is used. The temperature ranged between 40 and 90oC and the measurements were made from 10 to 10ºC. The accuracy of the temperature was 0.1ºC. [18]

Results and discussion

Figure 1 shows dependency of the ln dynamic viscosity on the T for studied olive oil at shear rate $3.3s^{-1}$, $6s^{-1}$, $10.6s^{-1}$, $17.87s^{-1}$, $30s^{-1}$, $52.95s^{-1}$, $80s^{-1}$ and $120s^{-1}$. [18]

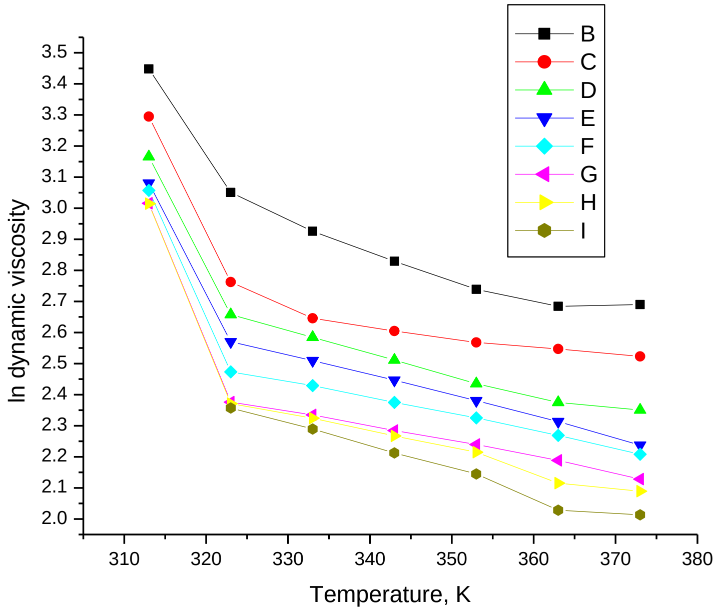

Fig.1. The correlation ln dynamic viscosity on the absolute temperature for olive oil at: B – $3.3s^{-1}$, C – $6s^{-1}$, D – $10.6s^{-1}$, E – $17.87s^{-1}$, F – $30s^{-1}$, G – $52.95s^{-1}$, H – $80s^{-1}$ and I – $120s^{-1}$

This article proposes one correlations (Eq.4) ln dynamic viscosity according to the temperature absolute for olive oil. We used the computer program Origin 6.0 to determine the constants $\ln\eta_0$, A_1 and t_1 and the correlation coefficients, R^2. The values of constants $\ln\eta_0$, A_1 and t_1 were determined by fitting exponential curves obtained for olive oil.[18]

$$\ln \eta = \ln\eta_0 + A_1 \exp(T/t_1) \quad (4)$$

The dependency of ln dynamic viscosity on the absolute temperature for olive oil at shear rate $3.3s^{-1}$, $6s^{-1}$, $10.6s^{-1}$, $17.87s^{-1}$ and $30s^{-1}$ (the black curves from Fig. 2, 3, 4,5 and 6) was fitting exponential as shown in figures 2, 3, 4, 5 and 6. The exponential dependence of ln dynamic viscosity on the absolute temperature for oilve oil at $3.3s^{-1}$ is described for equation (5):[18]

$$\eta = 2.73206 + 1.20222E12\exp(T/\ 11.13042) \quad (5)$$

where $\ln\eta_0$ =2.73206, t_1 = 11.13042 and A_1 = *1.20222E12*. The correlation coefficient is R^2 = 0.96973.[18]

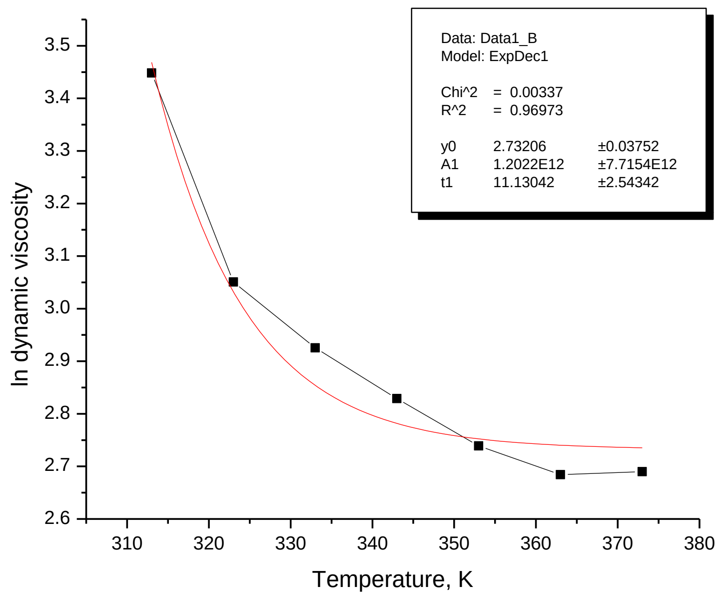

Fig. 2. The correlation ln dynamic viscosity on the absolute temperature at $3.3s^{-1}$

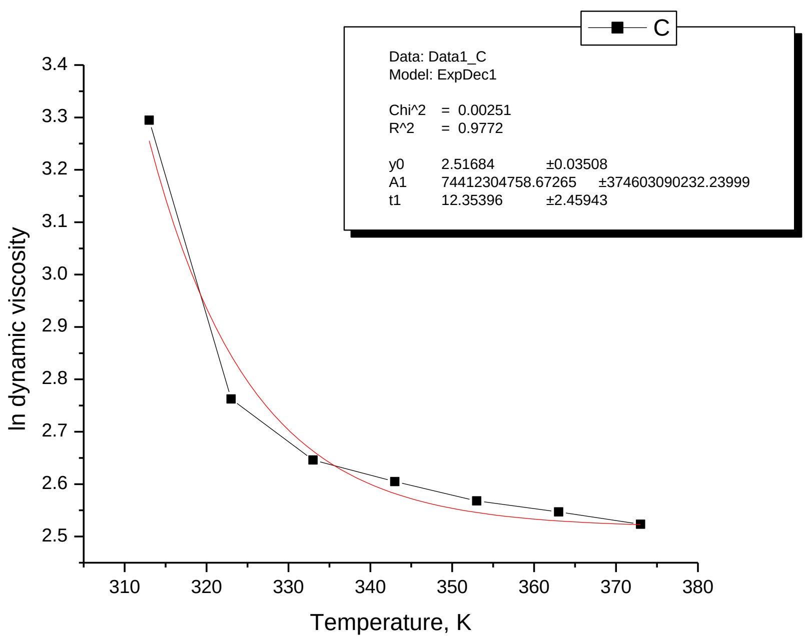

Fig. 3. The correlation ln dynamic viscosity on the absolute temperature at $6s^{-1}$

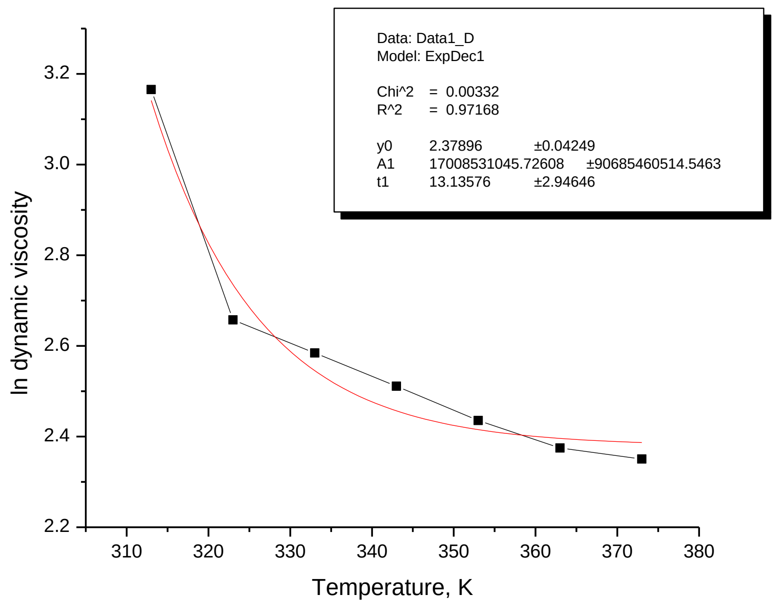

Fig. 4. The correlation ln dynamic viscosity on the absolute temperature at $10.6 s^{-1}$

The exponential dependence of ln dynamic viscosity on the temperature for olive oil at 30s-1 is described for equation (6):[18]

$$\eta = 2.2195 + 4.1979E8 \exp(-T/15.5549) \quad (6)$$

The value of the parameter $\ln\eta_0$ drops very little by main taining around 2 and the values of the parameters A_1 and t_1 vary within wide limits.[18]

Conclusions

The equations that best describe the temperature dependent ln dynamic viscosity of oilve oil studied are (4) for which correlation coefficients have values close to one. Olive oil ln dynamic viscosity decreases with increasing temperature at constant shear rate. Plotting the ln dynamic viscosity depending on temperature shows an exponential decline.

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