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The Effect of Temperature on the Dynmaic Viscosity of Acetone Sunflower-Seed Oil Mixtures

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The effect of acetone on the dynamic viscosity of sunflower-seed oil was studied under a dynamic heating regime at temeparuters ranging from 25°C to 50°C at 5°C intervals. Acetone dramatically reduced the viscosity of sunflower-seed oil. The reduction of viscosity was far less with further addition of acetone. A linear relationship was found between the density of sunflower-seed oil and temperature. The influence of a solvent on the density of the sunflower-seed oil/acetone solution can be accounted for by the mixing theory of ideal solutions, whereas the effect of temperature on the dynamic viscosity of the oil solution is best described by a modified Arrhenius equation.

Key Words: Acetone/oil solution, density, modelling, sunflower-seed oil, temperature effect, viscosity.

Introduction

Viscosity is a physicochemical property of practical importance. Several studies[1−4] have been carried out on the viscosity of oils and fats. As far as sunflower-seed oil is concerned, very little has been published on the influence of solvents on the viscosity of the oil solutions[5].

The effect of hydrogenation on the density and viscosity of sunflower-seed oil has been investigated by Topallar et al[6]. C Kapseu et al.[7] have determined the viscosities of cottonseed oil, fractionation solvents and their solutions.

An Ostwald viscometer or a falling ball viscometer are used to determine the viscosity of a liquid[8]. The effect of temperature on viscosity is as follows[9]:

$$\eta = A\, e^{E^{\neq}/RT} \tag{1}$$

where η is the absolute viscosity, **A** is a constant, $\mathbf{E}^{\neq}$ is the flow activation energy, **R** is the gas constant and **T** is the absolute temperature (K). According to this equation, viscosity decreases as temperature increases i.e. there is an inverse relationship between viscosity and temperature.

The dynamic viscosity (μ) of a solution can be obtained with the following equation[10]

$$\mu = d\eta \tag{2}$$

where **d** is the temperature-dependent density of the solution and η is the absolute viscosity

There is an inverse linear relationship between the density of sunflower-seed oil ($\mathbf{d_0}$) and temperature, **T (K)**, according to our previous work[6]:

$$d_0 = 1.6977 - 2.6754x10^{-3}T(K) \tag{3}$$

In a mixture of oil/acetone, the reciprocal of density of the mixture (i.e., total volume) is equal to the sum of partial volumes of the component solvents, i.e.,[10]

$$\frac{1}{d_{\text{mix}}} = \sum \frac{w}{d} = \frac{w_0}{d_0} + \frac{w_a}{d_a} \tag{4}$$

where $\mathbf{d}_{\text{mix}}, \mathbf{d_0}$ and $\mathbf{d_a}$ are densities of the mixture, sunflower-seed oil and acetone, and $\mathbf{w_0}$ and $\mathbf{w_a}$ are the weight fractions of sunflower-seed oil and acetone, respectively. Substituting $\mathbf{w_0}$ by $\mathbf{1 - w_a}$ and rearranging equation 4 gives

$$\frac{\mathbf{1}}{\mathbf{d}_{\text{mix}}} = \frac{1}{d_0} + \frac{d_0 - d_a}{d_0 d_a} w_a \tag{5}$$

Modelling of the temperature effect on the dynamic viscosity of oils is important and has been investigated by various researchers[11-14]. Equations of various forms have been used in these studies. Two-parameter (equations 6 and 7), and three-parameter equations (equations 8-11) were used:

$$\ln \mu = a + b \ln T \tag{6}$$

$$\ln \mu = a + \frac{b}{T} \tag{7}$$

$$\ln \mu = a + \frac{b}{T + c} \tag{8}$$

$$\ln \mu = a + \frac{b}{T} + \frac{c}{T^2} \tag{9}$$

$$\ln \mu = a + \frac{b}{T} + cT \tag{10}$$

$$\ln \mu = a + bT + cT^2 \tag{11}$$

where **a, b** and **c** are constants, and **T** is absolute temperature (K). Generally, the three-parameter equations gave a better fit than the two-parameter equations with a mean deviation of about 1% for canola oil with the former, compared with about 5 % with the latter[10].

In a study on the viscosity of oils and fatty acids, Noureddini et al[11] found that equation 10 was the best for correlating their viscosity data with temperature. Other researchers[12] used equation 9 for vegetable oils, including canola.

The purpose of this study was to elucidate the effect of temperature on the dynamic viscosity of sunflower-seed oil/acetone solution, and to model the temperature effect on the dynamic viscosity

Experimental

Materials

Refined, bleached and deodorized sunflower-seed oil was supplied by the Trakya Birlik Co. (Edirne, Turkey).

Acetone (Merck) was of analytical grade.

Methods

Solvent/oil solutions were prepared by mixing appropriate amounts of acetone with sunflower-seed oil at levels ranging from 20 to 80 % solvent (w/w).

The values of absolute viscosity were determined with a falling ball viscometer, Haake Type B3 Veb MLW (Medingen, Germany) as described previously[6].

The densities of the oil solutions were determined with a pycnometer[6].

Results and Discussion

Figure 1 shows the effect of adding various amounts of acetone and the absolute viscosity of sunflower-seed oil as a function of temperature. The corresponding viscosities of sunflower-seed oil and acetone are shown in Figures 2 and 3, respectively. The viscosity of acetone was only a fraction of sunflower-seed oil (a factor of 9.9615 at 25°C), and addition of acetone to sunflower-seed oil caused a considerable decrease in viscosity.

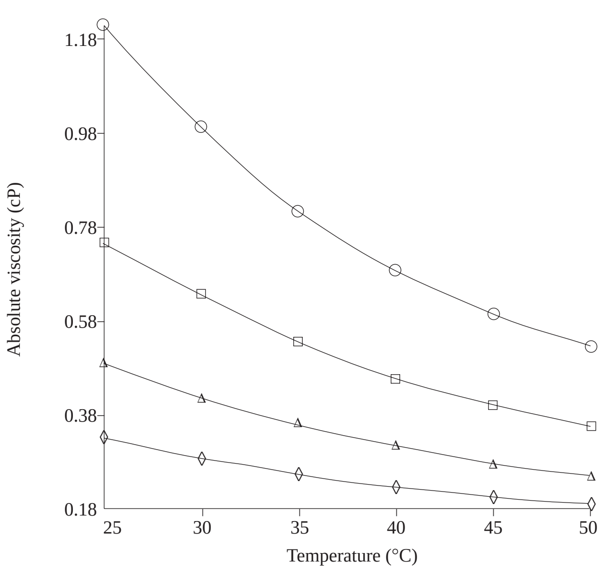

Figure 1. Absolute viscosity of acetone sunflower-seed oil solutions (%, w/w) as a function of temperature. **o:** 20 %, □: 40 %, Δ: 60% and ◇: %.

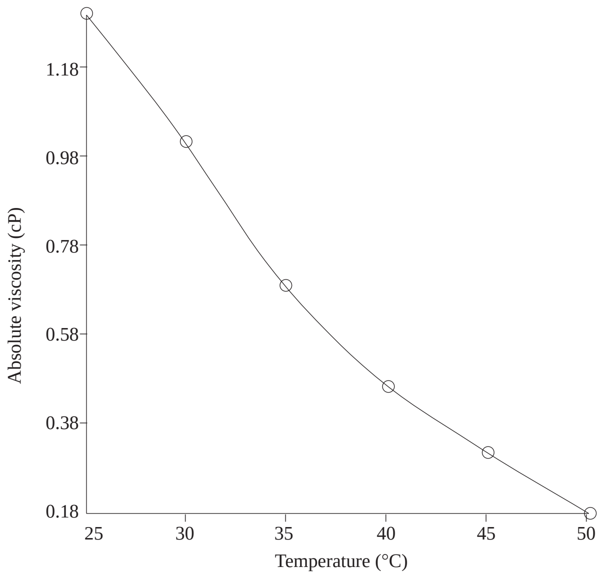

Figure 2. Influence of temperature on the absolute viscosity of sunflower-seed oil

Figure 4 shows the density of sunflower-seed oil as a function of temperature. Figure 5 shows the density of the sunflower-seed oil solution as a function of acetone content at 25°C. A linear relationship was obtained with equation 5. In addition, the density of acetone ($\mathbf{d_a}$), calculated with equation 5, was in good agreement with the experimental value (0.7906 from equation 5, compared with 0.7909, the experimental value).

Table 1 shows the dynamic viscosities of acetone sunflower-seed oil solution calculated by applying equations 2-5. The suitability of equations 6-11 in describing the temperature dependence of oil viscosity can be further studied by utilizing the viscosity data for the sunflower-seed oil solutions in Table 1.

For equations 8-11, the **a, b** and **c** constants were calculated as follows: the values of the dynamic viscosity and temperature in Table 1 were substituted into equations 8-11, and then three-unknown equations were reduced to one-unknown equations. However, the average deviations (%) were found from the differences by repeating the calculation procedure for each temperature. According to our experimental viscosity data, equations 6-11 gave an average deviation for viscosity of about 0.94, 1.02, 0.01, 1.51, 0.97 and 5.37 %, respectively. Therefore, equation 8 gave a better fit to our viscosity data, and were may prefer this equation to model the temperature effect on the viscosity of sunflower-seed oil. Figure 6 shows calculated dynamic viscosities accordin to equation 8. The corresponding constants for equation 8 are listed in Table 2.

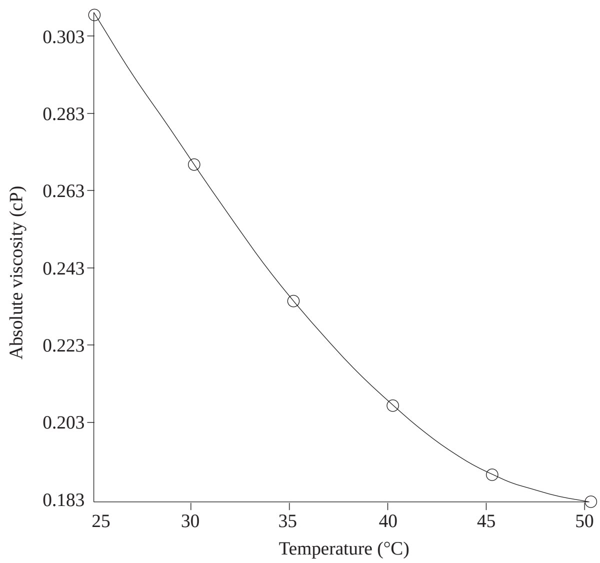

Figure 3. Influence of temperature on the absolute viscosity of acetone.

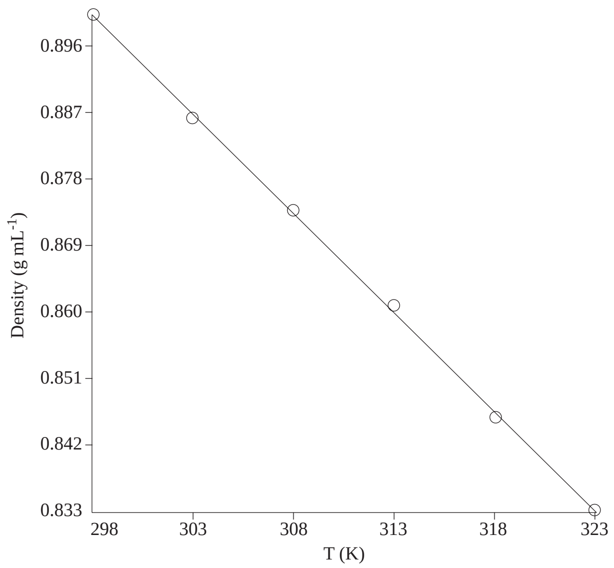

Figure 4. Influence of temperature on the density of sunflower-seed oil.

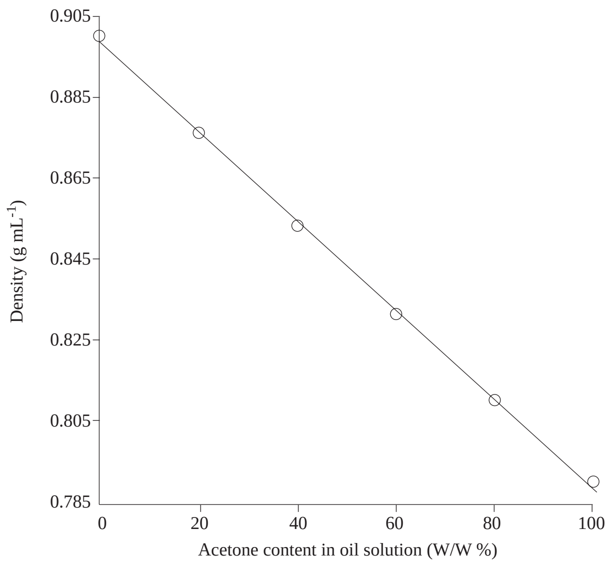

Figure 5. Relationship between the density of acetone sunflower-seed oil solution and its solvent content at 25° C.

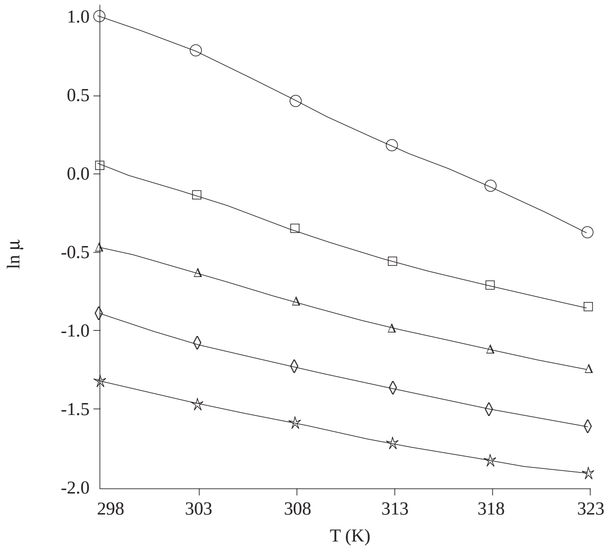

Figure 6. Calculated dynamic viscosities of sunflower-seed oil/acetone solutions, in accordance with equation 8 as a function of temperature at various acetone contents. **o:** sunflower-seed oil, □ : 20%, Δ : 40 %, ◇ : 60 % and ⋆ : 80 %.

Table 1. Calculated dynamic viscosities (cP) of sunflower-seed oil and acetone sunflower-seed oil solutions at various contents of acetone (%, w/w) and temperature (t° C).

(t°C)	Sunflower	20%	40%	60 %	80 %
25	2.7718	1.0618	0.6376	0.4107	0.2698
30	2.2059	0.8607	0.5379	0.3430	0.2322
35	1.6108	0.6976	0.4493	0.2952	0.2060
40	1.2098	0.5828	0.3791	0.2567	0.1809
45	0.9326	0.4966	0.3296	0.2231	0.1620
50	0.6973	0.4317	0.2894	0.1999	0.1496

Table 2. Constants of equation 8 for sunflower-seed oil and acetone/sunflower-seed oil solutions containing various amounts of acetone (%, w/w)

Acetone	a	b	c
Sunflower	2.4611	52.7014	-334.5582
20 %	2.0350	36.7722	-319.8294
40 %	1.9519	29.4487	-314.4497
60 %	1.7326	22.2360	-310.9341
80 %	1.7295	15.7653	-307.9426

The analysis of constant, **c**, for equation 8 in Table 2 showed that its average value for the sunflower-seed oil solutions may be considered constant as -317. Examination of the viscosity data for various oils, as reported by Noureddini et al.[11], demonstrated that the average value of constant, **c**, from equation 8 was about -156. When this fixed value for **c** is used in equation 8 it gives an average deviation for viscosity of about 6 % for oil and its solutions.

Conclusion

Addition of acetone to sunflower-seed oil causes a considerable decrease in viscosity. The density of the acetone/sunflower-seed oil solution decreases linearly as the acetone content in the solution increases.

The effect of temperature on the dynamic viscosity of acetone/sunflower-seed oil mixtures may be explained by the following equation:

$$\ln \mu = a + \frac{b}{T + c}$$

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