Viscosity, surface energies and surface heat capacities of three essential oils

Vanya Gandova¹*

¹Analytical and Physical Chemistry Department, University of Food Technologies, Plovdiv, Bulgaria

Abstract. In these study three essential oils were investigated in temperature range between 10 and 40°C. The surface energy and surface heat capacity were determined for them. Dynamic and kinematic viscosity were found in same temperature range. According investigations the best results are obtained for the Pinus sylvestris essential oil, after that for the Juniperus communis essential oil and Oreganum herachoticum, essential oil, respectively.

1 Introduction

Some essential oils are presented medicinal and flavoring applications. In them forty-three components were identified [1]. The essential oils of P. sylvestris were investigated with the impact of SO₂. It was seen to change of the amount of diterpenes and a shorter chain essential oils [2]. The composition of P. sylvestris essential oils from Lithuania was studied. Hydrodistillation-extraction was applied into essential oil. After gas chromatograph analysis 71 components were found [3]. Four essential oils from pinewood P. halepensis, P. pinaster, P. pinea and P. sylvestris were investigated. For analysis were used different essential oils components. Analysis was provided in the wounding and inoculation areas and in the whole plants [4]. Seasonally influence from October to June the terpene composition of Pinus oils was presented [5]. The juniper berry oil from Bulgaria was investigated in different ways. The juniper essential oil exhibits strong antioxidant activity because the hydrogen atom transfer was lower [6]. The juniper berries were analyzed by hydrodistillation and the simultaneous distillation-extraction method [7]. Hydrodistillation was applied into essential oil from Juniperus communis L. [8]. J. communis (L.) was analyzed and the oil was investigated [9]. Different parts of J. communis subsp. plants were used to obtain essential oils from them. The main components of the essential oils influence antioxidant capacity. Two from three investigated oils leaves of J. communis subsp. hemisphaerica and the fruit oil of J. oblong can possibilities to be use in very low concentrations in foods [10]. The Oreganum heracleoticum L was investigated. The natural herbicides used for seeds. As inhibition activity into oils was used α-amylase enzyme [11]. The chemical composition of oregano oil (Origanum vulgare) obtained from dried oregano leaves was obtained by GC/MS analysis. Oregano oil with gelatin films are presented [12]. The viscosity of Aleppo pine seeds in Bizerta were investigated by Rancimat test [13]. Some oil-resins used for various medicinal purposes were investigated and their viscosity and chemical composition were

* Corresponding author: gandova_71@abv.bg

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found viscosity [14]. The surface properties of three essential oils pure and in solutions were presented. Some good properties were seen in P. sylvestris essential oil [15]. Emulsification process in oregano essential oil were seen in different emulsions. They were prepared, analysed and stabilized using gelling agents as pectin gum Arabic [16].

The essential oils described above find exclusive application in perfumery, aromatherapy, cosmetics and medicine, and are also included in food products. Therefore, it is of interest to determine some physicochemical parameters, such as viscosity and surface tension, which are essential for their application.

The scope of this research is to found after experiment the viscosity in three oils and calculated surface properties as surface energies and surface heat capacities.

2 Materials and methods

2.1 Materials

The using oils are commercially obtained and presented from the south Bulgaria region.

2.2 Determination of viscosity

For viscosity was used a vertical falling viscometer. The dynamic kinematic viscosity was determined according [16, 19] and eq. 1.

\[
\eta = \frac{2 (\rho_l - \rho_b) g r^2}{9 v}
\]  

where: \( g \) – acceleration, \( m/s^2 \); \( \rho_l \) and \( \rho_b \) – densities of the liquid and ball, \( kg/m^3 \); \( r \) – radius, \( m \); \( v \) – speed of ball.

2.3 Determination of surface energy and surface heat capacity

Surface tension was determined according [15], surface energy and surface heat capacity were determined according authors [17, 18] and eqs. 2 and 3.

\[
E^s = \gamma - T \left( \frac{\partial \gamma}{\partial T} \right)
\]  

where: \( E^s \) – surface energy, \( N m^{-1} \); \( \gamma \) – surface tension, \( N m^{-1} \); \( \left( \frac{\partial \gamma}{\partial T} \right) \) – temperature gradient, \( N m^{-1} K^{-1} \); \( T \) – temperature, \( K \).

\[
C^s = -T \left( \frac{\partial^2 \gamma}{\partial T^2} \right)
\]  

where: \( C^s \) – surface heat capacity, \( N m^{-1} K^{-1} \); \( \left( \frac{\partial^2 \gamma}{\partial T^2} \right) \) – temperature gradient in area at second order transition, \( N m^{-1} K^{-1} \); \( T \) – temperature, \( K \).
2.4 Statistical analysis

For regression equations OriginPro 21.0 was used. Standard deviation (±) was determined with middle value between three measurements.

3 Results and discussion

The viscosity of liquids is presented as their deformation. A liquids viscosity connected with their thickness. The water presented so small viscosity compared with essential oils viscosity. In the present work viscosity was measured at four temperatures and temperature dependence was observed [20]. When the viscosity presented at high temperature linear dependence was seen. When the viscosity was presented at low temperature logarithmic dependence was observed. Viscosity is determined as dynamic viscosity when the rates presented as the rate of a deformation.

In fluid dynamics it is used a kinematic viscosity. In the essential oils P. sylvestris, J. communis and O. herachoticum two types of viscosity dynamic and kinematic were found. The results are presented on Figs. 1-3. All measurements are prepared at a temperature range between 10°C and 40°C. For the P. sylvestris essential oil results for two viscosities are presented on Fig. 1. The dynamic viscosity is 17.679 mPa.s at 10°C and decreases to 9.357 mPa.s at 40°C. Kinematic viscosity is 19.351 mm² s⁻¹ at 10°C and decrease to 10.371 mm² s⁻¹ at 40°C. According [13] P. halepensis seed oil presented values of dynamic viscosity 7.17mPa.s.

![Fig. 1. Temperature dependence of viscosity in P. sylvestris essential oil.](image)

For the J. communis essential oil results for two viscosities are presented on Fig. 2. The dynamic viscosity is 14.474 mPa.s at 10°C and decreases to 7.689 mPa.s at 40°C. Kinematic viscosity is 15.959 mm² s⁻¹ at 10°C and decreases to 8.653 mm² s⁻¹ at 40°C.

For the O. herachoticum essential oil results for two viscosities are presented on Fig. 3. The dynamic viscosity is 12.308 mPa.s at 10°C and decrease to 6.719 mPa.s at 40°C. Kinematic viscosity is 13.062 mm² s⁻¹ at 10°C and decrease to 7.615 mm² s⁻¹ at 40°C.

On the figures viscosities were change with change of temperature . At low temperatures appears a high value of viscosities but with increase of temperature the exponential dependence was seen [20].

The established differences in viscosity values is presented different composition of the studied essential oils - they contain monoterpane hydrocarbons and their oxygen derivatives, some of which are also thermolabile.
On experimental data according [15] were used for calculations. The surface energy usually connected with intermolecular bonds that are acting into a surface. Also it will be defined as the excess energy.

It is the work that will create an area of a particular surface or between two surfaces. There is the name "excess energy" acting between the two created surfaces. When the surface area increases the surface energy increases too. Surface heat capacity describes a physical property connected with thermal effects on the surfaces. High surface heat capacity connected with stability of the system.

The results obtained in this work are presented in Table 1. They show that the surface energy and surface heat capacity are so high in P. sylvestris essential oil. In this case this oil is determined as the most stable. In J. communis essential oil the values of the two surface parameters decrease and in O. herachoticum essential oil the surface values are the less.

According literature data [15] surface tension was determined and linear dependence between two surface parameters surface tension and surface energy obtained in this work was seen. The results are presented on Figs. 4-6.
Table 1. Surface energies and surface heat capacities of three essential oils.

<table>
<thead>
<tr>
<th>t °C</th>
<th><em>P. sylvestris</em></th>
<th><em>J. communis</em></th>
<th><em>O. herachoticum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Es, mN m⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>130.617 ±0.76</td>
<td>125.406±0.45</td>
<td>116.924±0.81</td>
</tr>
<tr>
<td>25</td>
<td>145.175 ±0.104</td>
<td>144.273±0.74</td>
<td>132.632±0.113</td>
</tr>
<tr>
<td>30</td>
<td>150.959 ±0.95</td>
<td>150.006±0.101</td>
<td>137.721±0.83</td>
</tr>
<tr>
<td>35</td>
<td>158.213 ±0.83</td>
<td>154.298±0.115</td>
<td>143.365±0.74</td>
</tr>
<tr>
<td>40</td>
<td>165.491 ±0.65</td>
<td>160.090±0.96</td>
<td>150.602±0.105</td>
</tr>
<tr>
<td></td>
<td>Cs, N m⁻¹ K⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>13765.74±0.365</td>
<td>12543.25±0.258</td>
<td>11263.83±0.311</td>
</tr>
<tr>
<td>25</td>
<td>14494.99±0.401</td>
<td>13207.73±0.317</td>
<td>11860.54±0.268</td>
</tr>
<tr>
<td>30</td>
<td>14738.07±0.387</td>
<td>13429.22±0.394</td>
<td>12059.44±0.205</td>
</tr>
<tr>
<td>35</td>
<td>14981.15±0.415</td>
<td>13650.72±0.175</td>
<td>12258.34±0.118</td>
</tr>
<tr>
<td>40</td>
<td>15224.23±0.323</td>
<td>13872.21±0.228</td>
<td>12457.24±0.303</td>
</tr>
</tbody>
</table>

**Fig. 4.** Linear dependence between surface tension [15] and surface energy in *P. sylvestris* essential oil.

**Fig. 5.** Linear dependence between surface tension [15] and surface energy in *J. communis* essential oil.
Fig. 6. Linear dependence between surface tension [15] and surface energy in *O. herachoticum* essential oil.

The measured viscosity and calculated surface properties with high stability described the *P. sylvestris* essential oil following of *J. communis* and *O. herachoticum* essential oils. The less stable is the *O. herachoticum* essential oil.

The differences in the values of this physicochemical parameter can also be explained by the content of various compounds in the composition of the studied essential oils, described above.

4 Conclusion

Three essential oils with determination of dynamic and kinematic viscosity at different temperatures were investigated. After experiment the highest value of viscosities is presented of *P. sylvestris* following from *J. communis* and *O. herachoticum*. The surface phenomena for three oil were observed. The *P. sylvestris* essential oil presented range between 130.617 - 165.491 mN m⁻¹ for surface energy, the *J. communis* presented range between 125.406 - 160.090 mN m⁻¹ and the *O. herachoticum* between 116.924 – 150.602 mN m⁻¹, respectively. The surface heat capacity presented values between 13765.74 - 15224.23 N m⁻¹ K⁻¹ for *P. sylvestris*, 12543.25 - 13872.21 N m⁻¹ K⁻¹ for *J. communis* and 11263.83 - 12457.24 N m⁻¹ K⁻¹ for *O. herachoticum*, respectively. According to the results the *P. sylvestris* essential oil presented good quality and stability.

References


