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

Vanya Gandova[1*]

[1]Analytical 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 *Junipperus 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 SO_2. 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

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.

$$\eta = \frac{2}{9}\frac{(\rho_l - \rho_b)gr^2}{v} \qquad (1)$$

where: g – acceleration, m/s^2; ρ_l and ρ_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.

$$E^s = \gamma - T\left(\frac{\partial\gamma}{\partial T}\right) \qquad (2)$$

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

$$C^s = -T\left(\frac{\partial^2\gamma}{\partial T^2}\right) \qquad (3)$$

where: C^s– surface heat capasity, 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 $mm^2\ s^{-1}$ at 10°C and decrease to 10.371 $mm^2\ s^{-1}$ at 40°C. According [13] *P. halepensis* seed oil presented values of dynamic viscosity 7.17mPa.s.

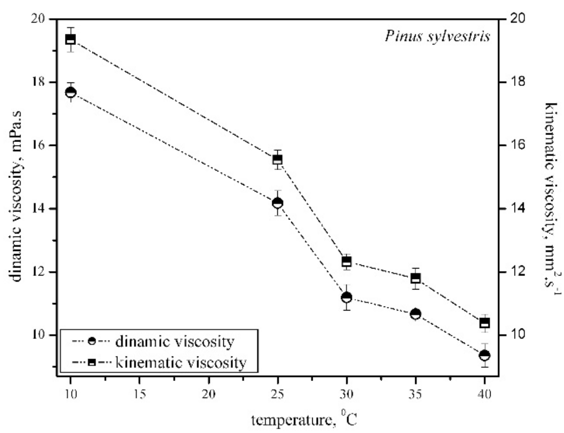

Fig. 1. Temperature dependence of viscosity in *P. sylvestris* essential oil.

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 $mm^2\ s^{-1}$ at 10°C and decreases to 8.653 $mm^2\ s^{-1}$ 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 $mm^2\ s^{-1}$ at 10°C and decrease to 7.615 $mm^2\ s^{-1}$ 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 monoterpene hydrocarbons and their oxygen derivatives, some of which are also thermolabile.

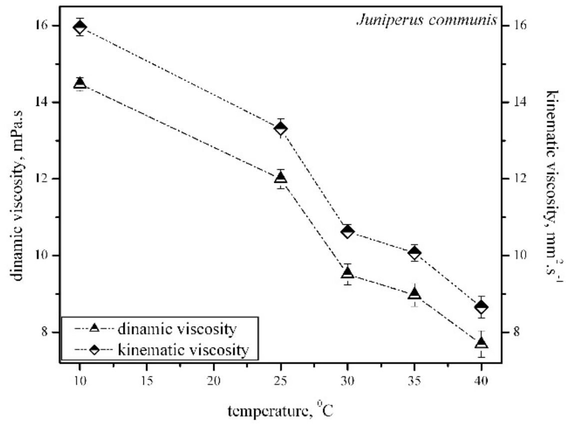

Fig. 2. Temperature dependence of viscosity in *J. communis* essential oil.

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.

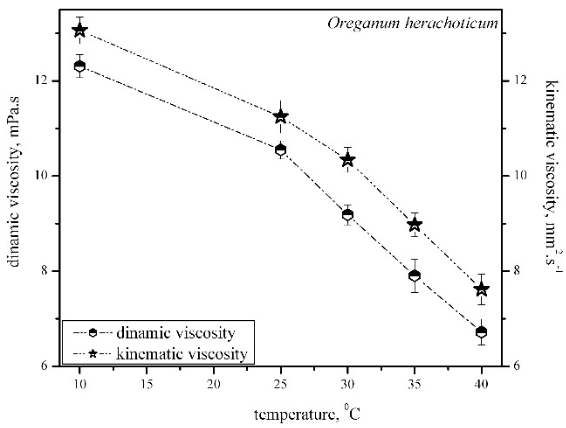

Fig. 3. Temperature dependence of viscosity in *O. herachoticum* essential oil.

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 capasity 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 surfase 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 capasiti of three essential oils.

t ^{0}C	*P. sylvestris*	*J. communis*	*O. herachoticum*
Es, mN m^{-1}			
10	130.617 ±0.76	125.406±0.45	116.924±0.81
25	145.175 ±0.104	144.273±0.74	132.632±0.113
30	150.959 ±0.95	150.006±0.101	137.721±0.83
35	158.213 ±0.83	154.298±0.115	143.365±0.74
40	165.491 ±0.65	160.090±0.96	150.602±0.105
Cs, N m^{-1} K^{-1}			
10	13765.74±0.365	12543.25±0.258	11263.83±0.311
25	14494.99±0.401	13207.73±0.317	11860.54±0.268
30	14738.07±0.387	13429.22±0.394	12059.44±0.205
35	14981.15±0.415	13650.72±0.175	12258.34±0.118
40	15224.23±0.323	13872.21±0.228	12457.24±0.303

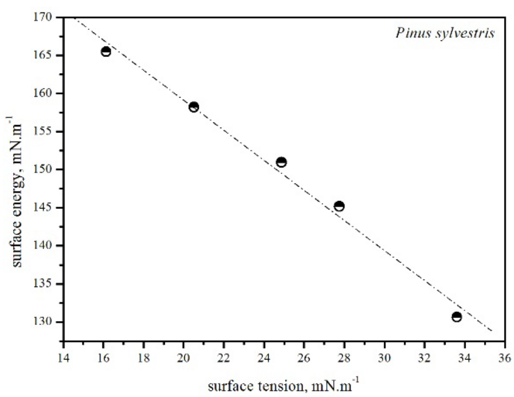

Fig. 4. Linear dependence between surface tension [15] and surface energy in *P. sylvestris* essential oil.

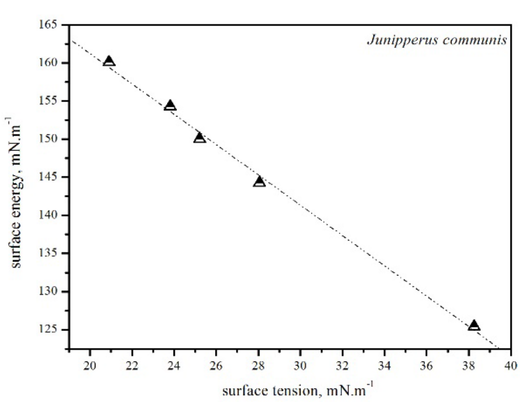

Fig. 5. Linear dependence between surface tension [15] and surface energy in *J. communis* essential oil.

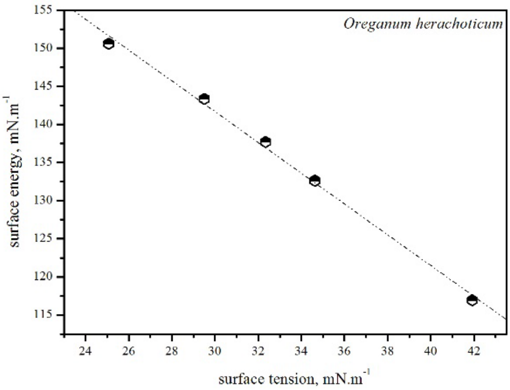

Fig. 6. Linear dependence between surface tension [15] and surface energy in *O. herachoticum* essential oil.

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

1. O. Ustun, E. Sezik, M. Kurkcuoglu, K. Base, Study ot the essential oil composition from Turkey. Chem. Nat. Comp. **42**, 26 (2006)
2. E. Kupcinskiene, A. Stikliene, A. Judzentiene, The essential oil qualitative and quantitative composition in the needles of *Pinus sylvestris* L. growing along industrial transects. Environ. Pollut. **155**, 481 (2008)
3. A. Judzentiene, E. Kupcinskiene, Chemical composition on essential oils from needles of *Pinus sylvestris* L. grown in Northern Lithuania. J. Essent. Oil Res. **20**, 26 (2006)
4. A. Rodrigues, M. Mendes, A. Lima, P. Barbosa, L. Ascensão, J. Barroso, L. Pedro, M. Mota, A. Figueiredo, *Pinus halepensis*, *Pinus pinaster*, *Pinus pinea* and *Pinus sylvestris* essential oils chemotypes and monoterpene hydrocarbon enantiomers, before and after inoculation with the pinewood nematode *Bursaphelenchus xylophilus*. Chem. Biodivers. **14**, e1600153 (2017)

5. M. Zafra, E. Garsia-Peregrin, Seasonal variations in the composition of *Pinus halepensis* and *Pinus sylvestris* twigs and needles essential oil. J. Agric. Sci. **86**, 1 (1976)
6. M. Höfer, I. Stoilova, E. Schmidt, J. Wanner, L. Jirovetz, D. Trifonova, L. Krastev, A. Krastanov, Chemical composition and antioxidant properties of juniper berry (*Juniperus communis* L.) essential oil. Action of the essential oil on the antioxidant protection of Saccharomyces cerevisiae model organism. Antioxidants. **3**, 81 (2014)
7. P. Chatzopoulou, S. Katsiotis, Procedures influencing the yield and the quality of the essential oil from *juniperus communis* L. berries. Pharm. Acta Helv. **70**, 24 (1995)
8. S. Milojevic, T. Stojanovic, R. Palic, M. Lazic, V. Veljkovic, Kinetics of distillation of essential oil from comminuted ripe juniper (*Juniperus communis* L.) berries. Biochem. Eng. J. **39**, 547 (2008)
9. A. Haziri, F. Faiku, A. Mehmeti, S. Govori, S. Abazi, M. Daci, I. Haziri, A. Bytyqi-Damoni, A. Mele, Antimicrobial properties of the essential oil *Juniperrus communis* (L.) growing in east part of Kosovo. Am. J. Pharmacol. Toxicol. **8**, 128 (2013)
10. S. Emami, B. Javadi, M. Hassanzadeh, Antioxidant activity of the essential oils of different parts of *Juniperus communis* subsp. hemisphaerica and *Juniperus oblong*. Pharm. Biol. **45**, 769 (2007)
11. G. Amato, L. Caputo, R. Francolino, M. Martino, V. De Feo, L. De Martino*, Origanum heracleoticum* essential oils: Chemical composition, phytotoxic and alpha-amylase inhibitory activities. Plants. **12**, 12040866 (2023)
12. J. Martucci, L. Gende, L. Neira, R. Ruseckaite, Oregano and lavender essential oils as antioxidant and antimicrobial additives of biogenic gelatin film. Ind. Crops Prod. **71**, 205 (2015)
13. S. Cheikh-Rouhou, B. Hentati, S. Besbes,1 C. Blecker, C. Deroanne, H. Attia, Chemical composition and lipid fraction characteristics of Aleppo pine (*Pinus halepensis* Mill.) seeds cultivated in Tunisia. Food Sci. and Technol. Inter. 12, 407 (2006)
14. M. T. Silva, L. L. Borges, T. de Sousa Fiuza, L. Tresvenzol, E. da Conceição, C. Batistac, C. Matos, V. da Veiga, R. Mourão, P. Ferri, J. de Paula, Viscosity of the oil-resins and chemical composition of the essential oils from oils-resins of *Copaifera multijuga* Hayne growing in the national forest Saracá-Taquera Brazil. J. Essent. Oil Bear. Pl. **20**, 1226 (2017)
15. Z. Gandov, S. Karaibryam, V. Gandova, I. Petrova, Temperature dependence of surface tension in three eseential oils with application as adjuvants in agriculture. In Proceedings of the Conference on Energy Efficiency and Agricultural Engineering (EE&AE), **1** (2022)
16. A. Salgado-Nava, R. Hernández-Nava, A. López-Malo, M.-T. Jiménez-Munguía, Antimicrobial activity of encapsulated mexican oregano (*Lippia berlandieri* Schauer) essential oil applied on bagels. Front. Sustain. Food Syst. **4**, 537091 (2020)
17. K. Fujisawa, T. Shiomi, F. Hamada, A. Nakajima, Van der Waals-like equations of state. I. Application to pure liquids. Polym. J. **3**, 993 (1981)
18. Ö. Çelebi, H. Fidan, I. Iliev, N. Petkova, I. Dincheva, V. Gandova, S. Stankov, A. Stoyanova, Chemical composition, biological activities, and surface tension properties of *Melissa officinalis* L. essential oil. Turk. J. Agric. For. **47**, 67 (2023)
19. V. Gandova, O. Teneva, Z. Petkova, I. Iliev, A. Stoyanova, Lipid composition and physicochemical parameters of flaxseed oil (*Linum usitatissimum* L.). Appl. Sci. **13**, 1 (2023)

20. S. Sahasrabudhe, V. Rodriguez-Martinez, M. O'Meara, B. Farkas, Density, viscosity, and surface tension of five vegetable oils at elevated temperatures: Measurement and modelling. Int. J. Food Prop. **20**, 1965 (2017)