

Dynamic solubility measurement of substances in supercritical fluids

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Abstract

The study of currently known methods and devices for processing plant materials has shown that during the study period, the greatest interest (about 31%) of patent holders is manifested in increasing the yield of extractive substances. If we take as an example a tea leaf, then indeed, the formation of conditions for a more complete release of the target components into the aqueous phase during brewing can provide a more profitable and economical consumption of tea raw materials.

The study of the thermodynamic principles of the use of supercritical fluid media and carbon dioxide, in particular, in the processing of plant materials and the processing of tea raw materials, as well as the development of methods for intensifying mass transfer to the aqueous phase when “brewing” tea leaves, are uniquely relevant tasks.

An important section of thermodynamics is the concept of phase equilibria in systems of different composition. And one of the key characteristics of phase equilibria is such a thing as the solubility of a substance, including in supercritical fluid media. Since solutions of substances in supercritical fluids are diluted, the dependence of the solubility of substances on temperature, pressure, and density of a pure solvent near its critical point is of practical interest.

The results of experimental studies of measuring the solubility of tannin in supercritical carbon dioxide by the dynamic method at a temperature of 308 and 333 K, in the pressure range from 8 to 26 MPa, are presented. The data obtained, firstly, indicate a low solubility of tannin in supercritical carbon dioxide, which is a positive moment for the implementation of the tea leaf pretreatment process in order to improve its biological potential, and secondly, a clear suppression of isolines is observed, which in turn indicates the presence of crossover behavior on solubility isotherms. Based on the results of the obtained experimental data on the solubility of tannin in supercritical carbon dioxide, a mathematical description of the solubility of tannin was carried out by the Peng-Robinson equation of state.

References

- [1] M.N. Eliseev, V.M. Poznyakovskiy. Commodity science examination of taste products. Textbook for high schools. Moscow: ed. center "Academy". 2006. P.304. (russian)
- [2] V.V. Pokhlebkina. The history of essential foods. Moscow: CJSC Publishing House Centropoligraph. 2004. P.367. (russian)
- [3] G.P. Stankovich, K.G. Duntsova. Commodity tea. Textbook for high schools. Moscow: INFRA-M. 2004. P.254. (russian)
- [4] E. Haslam. Natural polyphenols (vegetable tannins) as drugs: possible modes of action. *Journal of Natural Products*. 1996. Vol.59. No.2. P.205-215.
- [5] T. Tanaka, Y. Matsuo, Y. Saito. Solubility of tannins and preparation of oil-soluble derivatives. *Journal of Oleo Science*. 2018. Vol.67. No 10. P.1179-1187.
- [6] A.A. Semenov. Essay on the chemistry of natural compounds. Novosibirsk: Science. Siberian ed. RAS company. 2000. P.664. (russian)
- [7] M.R. Pansera, G.A. Iob, A.C. Atti-Santos, M. Rossato, L. Atti-Serafini, E. Cassel. Extraction of tannin by *Acacia mearnsii* with supercritical fluids. *Brazilian Archives of Biology and Technology*. 2004. Vol.47. No.6. P.995-998.
- [8] L.Y. Yarullin, F.M. Gumerov, Truong Nam Hung, I.I. Gilmutdinov, Z.I. Zaripov, F.R. Gabitov, and A.B. Remizov. The composition and structure of the tea leaves, processed in supercritical carbon dioxide. *Butlerov Communications*. 2016. Vol.48. No.11. P.88-100. ROI: jbc-02/16-48-11-88

- [9] Z.I. Zaripov, L.Y. Yarullin, F.M. Gumerov, Truong Nam Hung, F.R. Gabitov and V.A. Kayumova. Thermal effects dissolution main tea components in supercritical carbon dioxide. *Butlerov Communications*. **2017**. Vol.49. No.2. P.96-101. DOI: 10.37952/ROI-jbc-01/17-49-2-96
- [10] Zaripov, L.Y. Yarullin, F.M. Gumerov, Truong Nam Hung and F.R. Gabitov. Thermodynamic properties of binary and ternary mixtures containing cellulose, caffeine, carbon dioxide and water, in supercritical fluid conditions. *Butlerov Communications*. **2017**. Vol.49. No.3. P.92-100. DOI: 10.37952/ROI-jbc-01/17-49-3-92
- [11] J.W. Chen, F.N. Tsai. Solubilities of methoxybenzoic acid isomers in supercritical carbon dioxide. *Fluid phase equilibria*. **1995**. Vol.107. No.2. P.189-200.
- [12] M. McHugh, M.E. Paulaitis. Solid solubilities of naphthalene and biphenyl in supercritical carbon dioxide. *J. Chem. Eng. Data*. **1980**. Vol.25. No.4. P.326-329.
- [13] S. Mitra, J.W. Chen, D.S. Viswanath. Solubility and partial molar volumes of heavy aromatic hydrocarbons in supercritical CO₂. *J. Chem. Eng. Data*. **1988**. Vol.33. No.1. P.35-37.
- [14] Yu.V. Tsekhanskaya, M.B. Lomtev, E.V. Mushkina, Z.F. Kim. The solubility of naphthalene in ethylene and carbon dioxide under pressure. *Journal of Physical Chemistry*. **1964**. Vol.38. No.9. P.2166-2171. (russian)