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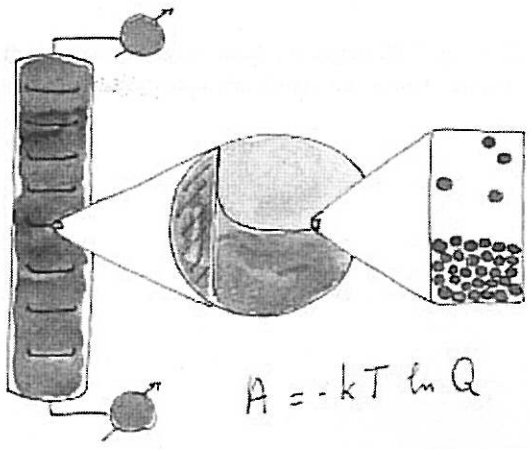

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Solubility of Flavonoids in Pure and Mixed Solvents

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1. Introduction

Flavonoids are receiving considerable attention due to their important biological and pharmacological properties [1]. In particular, the systematic study of their solubility in liquid solvents is being presented in the literature [2-8] to support the design of extraction, precipitation or crystallization processes. These compounds have a complex structure with a variety of functional groups that makes them difficult to represent by traditional thermodynamic models.

This work is divided in two parts. In the experimental section, new solubility data is presented for hesperetin in several pure and mixed solvents at different temperatures. The shake-flask method is applied, followed by quantitative analysis.

Concerning the thermodynamic modelling section, it presents the results obtained using the NRTL-SAC model [9,10], in combination with the reference solvent approach (RSA) [11,12], to describe the solid-liquid equilibrium of several flavonoids in pure and mixed solvents. The NRTL-SAC model represents molecules by conceptual segments: hydrophobic, polar attractive or repulsive and hydrophilic. For each solute, four parameters are calculated using experimental solubility data in a selected set of solvents that should, preferably, cover a wide range of molecular interactions. Additionally, the application of the RSA approach avoids the knowledge of the thermal properties that are often unknown for flavonoids. Finally, the excess solubility approach (ESA) [13-15] with one parameter correlative model is also applied to describe the solubility in mixed solvents.

2. Experimental section

The analytical gravimetric method combined with UV analysis were the experimental techniques chosen to perform the measurements, as described in detail elsewhere [16]. New solubility data for hesperetin is presented both in pure solvents (acetonitrile, MTBE and DMSO) and in mixed solvents (water/methanol, water/acetone), in the temperature range between 25 and 40 °C.

3. Thermodynamic modeling

The NRTL-SAC model showed to be an appropriate tool to represent the solubility of some representative flavonoids in pure solvents suggesting its ability to predict solubility in pure solvents not considered during the correlation procedure. A summary of the correlation and

prediction results is presented on Figures 1 and 2, respectively, for a selected group of flavonoids and solvents. For apigenin and genistein, the NRTL-SAC model was combined with the RSA methodology.

For mixed solvents difficulties are found, particularly, for systems presenting a solubility maximum. The excess solubility approach with one parameter correlative model allowed an improved description of those ternary mixtures (luteolin in water/ethanol; quercetin in water/methanol or water/ethanol; apigenin in water/ethanol). An average absolute deviation of 23% was obtained though improvements are needed for the description of the solubility change with temperature.

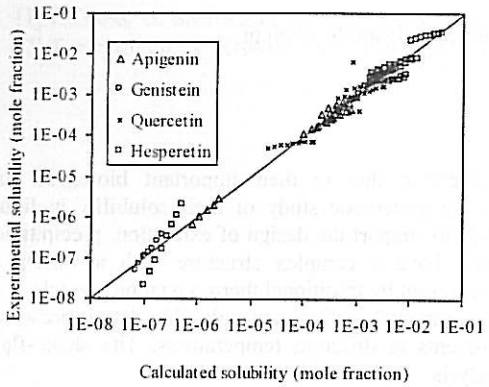

Figure 1. Experimental data [2-8, this work] *versus* NRTL-SAC correlation results for the solubility of flavonoids in pure solvents.

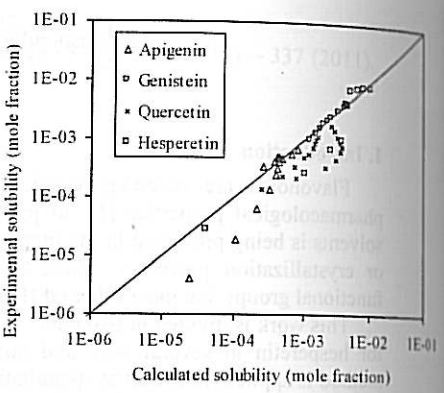

Figure 2. Experimental data [2-8, this work] *versus* NRTL-SAC predictions for the solubility of flavonoids in pure and mixed solvents.

4. Conclusion

New solubility data of hesperetin in the temperature range between 25 and 40 °C was measured in several pure and mixed solvents.

Even if some outliers can be found, NRTL-SAC predicts the solubility changing with the solvent type. Combining NRTL-SAC with RSA results improved, and for substances with unknown melting properties its usefulness was shown.

Excess solubility approach with one parameter correlative model allowed a much better description of the solubility in mixed solvents.

References

[1] B.H. Havsteen, *Pharmacol. Ther.*, 96, 67–202 (2002).
[2] J.G. Wu, J. Ge, Y.P. Zhang, Y. Yu and X.Y. Zhang, *J. Chem. Eng. Data*, 55, 5286–5288 (2010).
[3] R.S. Razmara, A. Daneshfar and R. Sahraei, *J. Chem. Eng. Data*, 55, 3934–3936 (2010).
[4] L. Chebil, C. Humeau, J. Anthoni, F. Dehez, J.M. Engasser and M. Ghoul, *J. Chem. Eng. Data*, 52, 1552-1556 (2007).
[5] L. Liu and J. Chen, *J. Chem. Eng. Data*, 53, 1649–1650 (2008).

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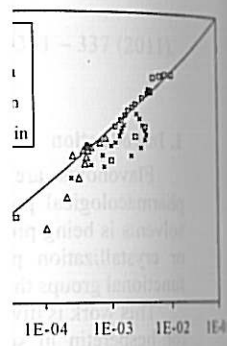

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934–3936 (2010).
Ghoul, *J. Chem. Eng.*

[6] M. Xiao, Y. Shao, W. Yan and Z. Zhang, *J. Chem. Thermodyn.*, 43, 240–243 (2011).
[7] O. Ferreira and S.P. Pinho, *3rd International Symposium on Biothermodynamics*, Bologna, September 6th (2010).
[8] M. Xiao, W. Yan and Z. Zhang, *J. Chem. Eng. Data*, 55, 3346–3348 (2010).
[9] C.C. Chen and Y.H. Song, *Ind. Eng. Chem. Res.*, 43, 8354-8362 (2004).
[10] C.C. Chen and P.A. Crafts, *Ind. Eng. Chem. Res.*, 45, 4816-4824 (2006).
[11] J. Abildskov and J.P. O'Connell, *Ind. Eng. Chem. Res.*, 42, 5622-5634 (2003).
[12] J. Abildskov and J.P. O'Connell, *Fluid Phase Equilib.*, 228, 395-400 (2005).
[13] C.J. Orella and D.J. Kirwan, *Ind. Eng. Chem. Res.* 30, 1040-1045 (1991).
[14] S.P. Pinho and E.A. Macedo, in *Developments and Applications in Solubilities*, Edited by Trevor Letcher, Royal Society of Chemistry, 309-326 (2007).
[15] M.T. Gude, H.H.J. Meuwissen, L.A.M. van der Wielen and K.C.A.M. Luyben, *Ind. Eng. Chem. Res.*, 35, 4700-4712 (1996).
[16] L.A. Ferreira, E.A. Macedo and S.P. Pinho, *Ind. Eng. Chem. Res.*, 44, 8892-8898 (2005).