Measurements of Water Activity in "Sugar" + Sodium Chloride + Water Systems at 25 °C

J. F. Comesaña,[†] A. Correa,[*,†] and A. Sereno[‡]

Department of Chemical Engineering, University of Vigo, 36200 Vigo, Spain, and Department of Chemical Engineering, University of Porto, Rua dos Bragas, 4099 Porto Codex, Portugal

Water activities in aqueous solutions of xylose, fructose, and glucose with sodium chloride were measured and correlated with an empirical equation. Parameters for the equation were obtained, and, from them, values of water activity were calculated with an average relative deviation of less than 0.17% for the three ternary systems studied.

Introduction

A major concern in food technology is to prevent factors enhancing degradation reactions mainly due to microbial growth. Water is a major requirement for such reactions, being thus important to lower the activity of water (a_w) in the food. This may be achieved with the help of humectants such as some sugars and salts (Bone, 1973; Sloan and Labuza, 1975; Karel, 1989).

Unfortunately some of them have a negative effect on taste and other organoleptic properties. Attempts to combine several solutes were made in order to reduce their individual amount. In other cases their combination can result in a mutual synergistic effect (Bone, 1973).

In this work values of water activity for ternary systems xylose + sodium chloride + water, fructose + sodium chloride + water, and glucose + sodium chloride + water at 25 °C were measured with an electric hygrometer.

Experimental Section

Distilled water and analytical grade reagents with a minimum of 99.5% purity supplied by Merck (xylose and fructose), May&Baker (glucose), and Carlo Erba (sodium chloride) were used. Reagents were previously dried in an oven at 105 °C (80 °C for fructose because of its lower melting point) and subsequently kept in a desiccator over silica gel until use. All solutions were prepared from water and reagents by mass using a Mettler AE 240 analytical balance to 0.1 mg.

Experimental water activities were measured with a Thermoconstanter electric hygrometer (Defensor-Novasina AG) as described by Stamp et al. (1984). The instrument was previously calibrated using a_w standards supplied by the manufacturer and this calibration verified by means of sodium chloride solutions of different concentration with known water activity (Robinson and Stokes, 1970). Under these conditions it was determined that a precision in a_w measurements of ±0.005 can be obtained, in agreement with the results reported by Troller (1983).

Table 1. Water Activities for Xylose (1) + Sodium Chloride (2) + Water (3) at 25 °C

$m/(mol\cdot kg^{-1})$			
xylose	NaCl	a_w(expt)	a_w(calc)
1.6081	0.5086	0.954	0.954
0.9009	0.9400	0.953	0.953
0.6103	1.6992	0.932	0.932
2.6251	0.6108	0.931	0.932
2.0072	1.0327	0.930	0.930
1.9266	1.5000	0.914	0.915
1.6927	1.6500	0.910	0.914
1.0110	2.1229	0.908	0.909
2.8973	1.2190	0.905	0.907
3.1875	1.0419	0.904	0.907
2.5346	1.5610	0.900	0.901
0.5080	2.5983	0.897	0.900
1.9780	1.9716	0.895	0.897
1.7334	2.5077	0.882	0.881
3.2392	2.0606	0.870	0.870
0.9604	3.2267	0.866	0.867
2.5118	2.5939	0.865	0.863
2.9063	2.5224	0.861	0.859
1.0563	3.4860	0.857	0.854
2.0216	3.0486	0.857	0.855

Samples of each solution (about 10 mL) were left in the hygrometer at (25 ± 0.2) °C until equilibrium was reached after a period ranging from 5 h for the more concentrated solutions to 24 h for the less concentrated ones.

Each water activity measurement was the average of three determinations, found to be sufficient to reach the indicated precision with the instrument for the a_w range studied (Kitic et al., 1986).

Results and Discussion

The water activities for xylose + sodium chloride + water, fructose + sodium chloride + water, and glucose + sodium chloride + water are presented in Tables 1−3.

Before analysis of these data, values of water activity at 25 °C for the binary systems xylose + water (Uedaira and Uedaira, 1969), fructose + water (Correa et al., 1994), glucose + water (Miyajima et al., 1983), and sodium chloride + water (Robinson and Stokes, 1970) were correlated using an empirical equation of the form (Lin et al., 1996)

$$a_{wi} = 1 + C_i m_i + C_{ii} m_i^2 \qquad (1)$$

* To whom correspondence should be addressed. E-mail: acorrea@uvigo.es.
† University of Vigo.
‡ University of Porto.

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Table 2. Water Activities for Fructose (1) + Sodium Chloride (2) + Water (3) Systems at 25 °C

m/(mol·kg^{-1})			
fructose	NaCl	a_w(expt)	a_w(calc)
1.0054	0.4965	0.967	0.967
0.5376	1.0148	0.957	0.958
1.6379	0.5140	0.956	0.954
1.9124	0.3607	0.955	0.954
0.5190	1.3729	0.943	0.946
2.5041	0.5300	0.936	0.938
0.9344	1.4634	0.934	0.936
0.5509	1.7505	0.929	0.932
1.0110	1.8223	0.923	0.923
2.0013	1.3990	0.920	0.921
3.4973	0.4356	0.918	0.920
3.9690	1.0056	0.895	0.895
2.1828	2.1765	0.890	0.892
1.0224	2.7487	0.889	0.889
3.2476	1.7064	0.888	0.888
4.0830	1.3780	0.885	0.882
3.5637	1.9255	0.876	0.876
4.0096	1.7964	0.868	0.871
2.1689	3.0061	0.864	0.863
3.2018	2.5352	0.864	0.863
4.0565	2.1044	0.863	0.861
1.0307	3.5198	0.859	0.859

Table 3. Water Activities for Glucose (1) + Sodium Chloride (2) + Water (3) at 25 °C

m/(mol·kg^{-1})			
glucose	NaCl	a_w(expt)	a_w(calc)
0.5138	0.5068	0.974	0.974
1.0499	0.5481	0.965	0.963
0.5042	1.0041	0.959	0.958
1.1491	1.0832	0.947	0.944
2.1331	0.5908	0.944	0.942
1.0075	1.1603	0.944	0.944
1.9767	1.0180	0.929	0.931
2.0071	1.0500	0.928	0.929
3.0434	0.5252	0.925	0.926
0.5326	1.9831	0.921	0.923
2.5295	1.1022	0.917	0.917
1.5103	1.8109	0.911	0.912
3.9006	0.5661	0.907	0.908
2.4682	1.6980	0.898	0.898
1.4962	2.1857	0.896	0.898
2.0329	2.0071	0.894	0.895
2.0076	2.0819	0.891	0.893
4.1368	1.0008	0.889	0.890
2.9690	2.0104	0.880	0.878
0.5388	2.9367	0.887	0.886
1.0174	2.9474	0.879	0.878
3.7823	1.9622	0.864	0.864
0.5142	3.6221	0.858	0.859
2.0259	3.0603	0.857	0.855

where m represents the molal concentration of solutes in solution and subscript i is 1 for sugars and 2 for sodium chloride. Values obtained for parameters C_i and C_{ii} are presented in Table 4. Equation 1 could represent the water activities of binary systems with an average relative deviation always less than 0.09%.

For the ternary systems, the equation proposed by Lin et al. (1996) has the form

$$a_w - 1 = (a_{w1} - 1) + (a_{w2} - 1) + C_{12}m_1m_2$$
$$= C_1m_1 + C_{11}m_1^2 + C_2m_2 + C_{22}m_2^2 + C_{12}m_1m_2 \quad (2)$$

For this model, only parameter C_{12} was obtained from ternary data. The values for the present systems are also included in Table 4.

With listed parameters in Table 4, a_w was calculated and their values are presented in Tables 1−3. The average relative deviations of 0.16% for the system with xylose, 0.15% for the system with fructose, and 0.14% for the one with glucose were obtained. Figures 1−3 compare experi-

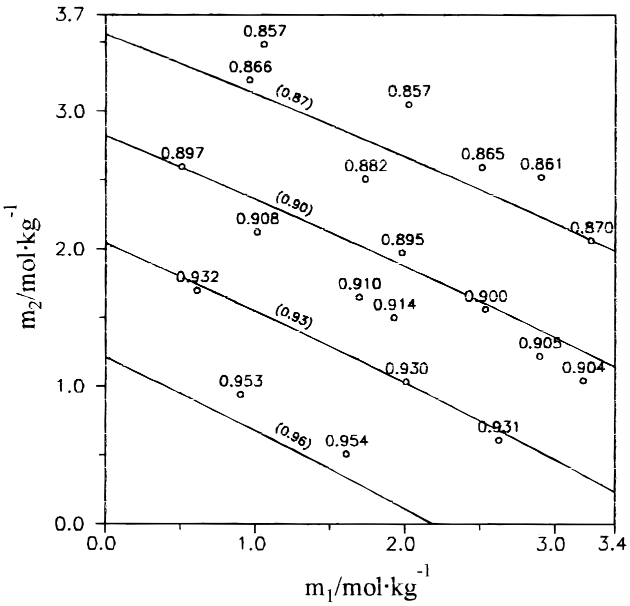

Figure 1. Calculated water isoactivity plot for xylose (1) + NaCl (2) + water (3) (○, water activity, experimental).

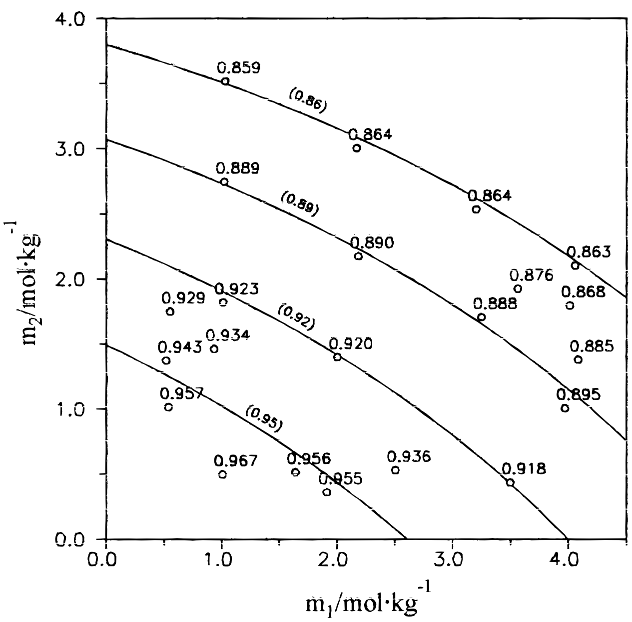

Figure 2. Calculated water isoactivity plot for fructose (1) + NaCl (2) + water (3) (○, water activity, experimental).

Table 4. Parameters for Equation 2 for Sugar + Sodium Chloride + Water Systems

	param				
syst	10^2C_1	10^4C_{11}	10^2C_2	10^3C_{22}	10^3C_{12}
xylose + NaCl + water	−1.8013	−1.2364	−3.1327	−1.4553	0.0899
fructose + NaCl + water	−1.7598	−6.0317	−3.1327	−1.4553	1.7433
glucose + NaCl + water	−1.8230	−2.3437	−3.1327	−1.4553	0.4533

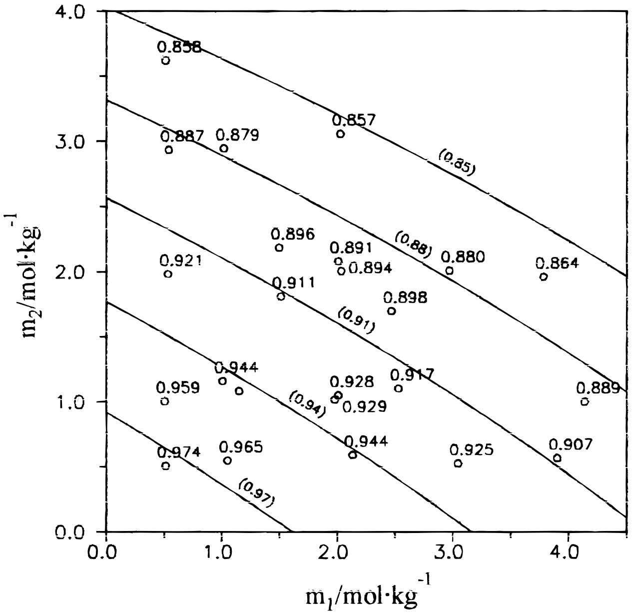

Figure 3. Calculated water isoactivity plot for glucose (1) + NaCl (2) + water (3) (○, water activity, experimental).

mental and calculated values of a_w for the ternary systems studied.

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