



Investigations on the Effects of Salts and Carbohydrates on L-lysine in Aqueous System at T=293.15K

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<http://dx.doi.org/10.13005/ojc/370327>

(Received: May 22, 2021; Accepted: June 25, 2021)

ABSTRACT

Physicochemical studies of amino acids in an aqueous medium can provide significant knowledge about the stabilization mechanism of proteins. In this study, the viscosity (η), surface tension (γ), density (ρ) and the specific conductance (κ) measurements have been carried out for amino acid L-lysine (0.02 to 1.6M) in aqueous solutions at 293.15K. The experimental data shows that there is an increase in the viscosity, surface tension, conductance, and density of the L-lysine with and without glucose, sucrose, sodium chloride, and potassium chloride with concentration. The solute-solute and solute-solvent interactions have been discussed on the basis of all physicochemical parameters.

Keywords: Physico-chemical properties, L-lysine, Glucose, Sucrose, Sodium chloride, Potassium chloride.

INTRODUCTION

The stabilization of the native conformations of biological macromolecules like proteins, carbohydrates, nucleic acids results due to several interactions such as hydrophobic, hydrogen bonding, and electrostatic force of attraction. Solute presence greatly affects the physicochemical properties of proteins. The study of solute-solvent and solute-solute interactions is very exigent due to their valuable contribution to the energetics of protein denaturation. Biochemical processes in living organisms are governed by the interaction of carbohydrates and salts. Proteins also play a significant role in these processes but the study of these interactions is somewhat difficult because proteins are very large complex molecules. Therefore, similar model compounds have been used to study these interactions.

The model compounds and building blocks of protein molecules are amino acids. They provide valuable information for a better understanding of the behaviour of biological macromolecules or proteins^{1,2}. The effect of the presence of electrolytes in solutions of biochemicals is of interest in many separation processes, such as the reverse micellar extraction of amino acids and proteins which may not occur without the presence of an electrolyte³. Proteins-carbohydrates interactions play a significant role in a wide range of biochemical processes in living systems. Particularly, carbohydrates located at cell surfaces are very important as receptors concerning the bioactive structures of hormones, enzymes, viruses, antibodies, etc.^{4,6}. These interactions are important for different industries like immunology, biosynthesis, pharmacology, medicine, cosmetic industry, and food industries^{7,8}. L-lysine is a simplest amino acid and has no enantiomers due to the presence of two hydrogen



atoms on a central carbon atom. A high concentration of L-lysine is found in the human body especially in the skin, joints, muscle tissue, etc. Therefore, the interaction of L-lysine with other materials plays an important role in various fields like pharmaceutical, food industries, material science, etc.

Earlier studies have reported the density and viscosity data for different mixtures of amino acids, carbohydrates, and electrolytes and utilized these data to deduce the thermodynamic properties (relative viscosity, Jones–Dole coefficient, etc.)⁹⁻¹³.

In the present paper, densities, viscosities, electrical conductivity, and surface tension of L-lysine (0.2-0.16 M) in aqueous sodium chloride (0.2M), potassium chloride (0.2M), Glucose (0.2M), Sucrose (0.2M) solutions have been determined experimentally at 293.15 K.

MATERIALS AND METHODS

L-lysine (Batch no.-CN170510), was purchased from Qualikems, India. 4.45 g L-lysine was weighted to make a 250 mL stock solution of 0.2M by using distilled water. By using the stock solution, eight samples of L-lysine of different concentrations (0.02, 0.04, 0.06, 0.08, 0.1, 0.12, 0.14, and 0.16 M) were prepared. To check the intermolecular interactions with L-lysine, 20 mL of each 0.2 M Glucose (G8270, Qualikems, India), 0.2 M Sucrose (Batch No.-IK1030BC01, Qualikems, India), 0.02 M Sodium chloride (Batch No-0981, Reidel India Chemicals) and 0.02 M Potassium chloride (Batch No.-090514, Central Durg House, India) were prepared.

Determination of Viscosity

An Ubbelohde type viscometer was used to measure the viscosity data. The viscometer was first to be calibrated with double distilled water and fitted in a thermostatic water bath by using a clamp stand. The sample solution was filled in viscometer using a rubber bulb up to the mark and allowed to flow through its capillary tube between two etched marks. The time of flow of the liquid sample was measured using a stopwatch of least count 0.1 s. Measurement of each sample was repeated three times to minimize errors and finally, the average value was taken. Poiseuille's equation was used to calculate the viscosity of sample solutions

$$\eta = \frac{\pi p h g r^4 t}{8 l V} \quad (1)$$

Where ρ is the density of the amino acids solutions, h is the height of the viscometer column, g is the acceleration due to gravity, r is the radius of the capillary tube, l is the length of a capillary tube, t is the time of fall of the sample solution and V is the volume.

Determination of Density

A single capillary pycnometer made by Borosil glass with a close-fitting ground glass stopper having a bulb capacity of $10 \times 10^{-6} \text{ m}^3$ was used to measure the density data. The pycnometer was cleaned and rinsed with double distilled water and dried. After drying, a pycnometer was fitted in a thermostatic water bath and calibrated using double distilled water at 293.15 K. Sample solutions were employed in the pycnometer to measure the density.

Determination of Surface Tension

A stalagmometer was used to determine the surface tension. The stalagmometer was clamped vertically in a clamp stand. Double distilled water was sucked in the apparatus up to the upper mark. The numbers of drops were counted while water flows from the upper mark to the lower mark. After cleaning the stalagmometer, the whole process was employed for the sample solutions. The process was repeated three times to remove errors. The surface tension was calculated by the following formula.

$$\frac{\gamma_l}{\gamma_w} = \frac{n_w d_l}{n_l d_w} \quad (2)$$

Where γ_l is the surface tension of the sample solution, γ_w is the surface tension of the double-distilled water, n_l is the number of drops of the sample solution, n_w is the number of drops of the double-distilled water, d_l is the density of sample solution, and d_w is the density of double-distilled water.

Determination of Electrical Conductivity

A conductivity meter (LT-16, Labtronics) having a cell constant 0.97 cm^{-1} was used to determine the conductivity of all samples. To measure the conductance, the conductivity cell was

rinsed with double distilled water and wiped smoothly with tissue paper. Now, the cell was dipped in a small beaker containing a sample solution. After setting constant, conductance reading was noted down. The whole process was repeated for the other samples.

RESULTS AND DISCUSSION

Viscosity (η), density (ρ), surface tension (γ) and specific conductivity (κ) data of L-lysine with increasing concentration in the presence of glucose, sucrose, NaCl, and KCl are presented in the table. Viscosity data for all samples were determined by using equation (1). We have found that there was an enhancement in viscosity of L-lysine with concentration. The enhancement of viscosity of a solution with concentration is due to the structural effect induced by the solute-solvent interactions. Moreover, under torsional forces, the solute particles lying thenceforward to the fluid stream lines. The absorption energy requires when these solute particles will tend to rotate, resulting in an increase in the viscosity of the solution¹⁴.

The viscosity results for the system (salt + amino acid + water) were also found to be increased with increasing the concentration of L-lysine in solution as shown in Fig. 1. This may be attributed to an increase in the solute-solvent or zwitterion interaction with a successive increase in the number of amino acid molecules/zwitterions in the solution. The zwitterionic segment of the amino acid compresses the volume of solvent due to the electrostriction effect¹⁵, which may, in turn, cause more frictional resistance to the flow of solution. The viscosity and density of L-lysine in water and aqueous glucose were measured and shown in Fig. 1 and Fig. 2 respectively. Fig. 1 and Fig. 2 show that there was a strong solute-solvent (hydrophilic-ionic group and hydrophilic-hydrophilic group) interaction in this system, which increases with an increase in glucose concentration. The viscosity of the sample containing sucrose was highest in comparison to all samples but slightly similar to a sample containing glucose and smallest for

L-lysine itself. The viscosities of salts were found to be higher than L-lysine itself while smaller than the sample containing sugars.

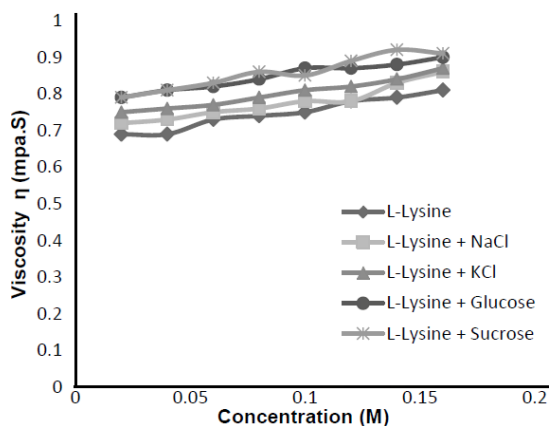


Fig. 1. Viscosity versus concentration of L-lysine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K

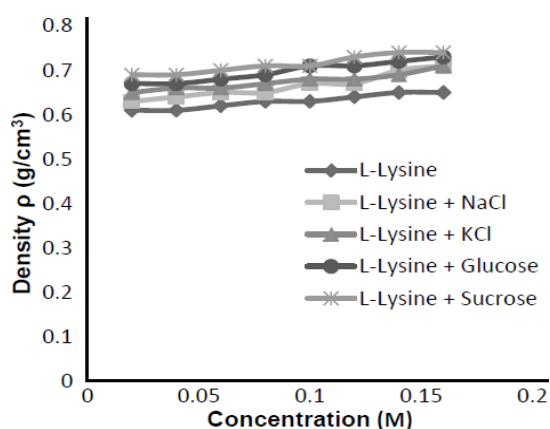


Fig. 2. Density versus concentration of L-lysine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K

This study suggests that the surface tension was increased with an increase in the concentration of L-lysine with and without glucose, sucrose, NaCl, and KCl (Fig. 3). The surface tension of the sample of L-lysine + sucrose is highest and for glucose smaller than sucrose while smallest in the sample containing NaCl were found. As we know NaCl and KCl are strong electrolytes which means that they dissociate into their ions when placed in solution. It turns out that the interaction between the cations and a partial negative ion of solution and anions and the partial positive ion of solution although they disrupt part of the hydrogen bonding. In the case of the sample containing KCl, we found that the surface tension is smaller than those obtained in the case of glucose and sucrose but higher than L-lysine itself.

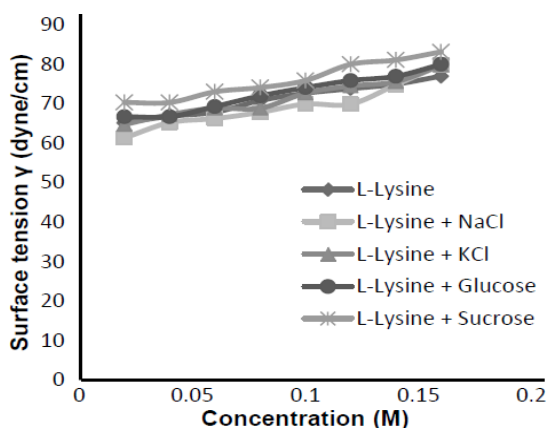


Fig. 3. Surface tension versus concentration of L-Lysine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K

In this study, we have shown that the density of L-lysine increases with concentration (Fig. 2). There was an increase in density with concentration suggests a solute-solvent interaction exists between the L-lysine and water. Due to the presence of solute molecules, the volume of solvent reduces resulting increase in density. Moreover, the structure maker of the solvent due to the added solute may be explained by the enhancement of density. On the other hand, the decrease in density with concentration is interpreted as the structure breaker of the solvent¹⁶. The density of L-lysine solution containing sucrose was highest while smallest in the case of the sample containing L-lysine itself. In our results, the density of the sample containing glucose was slightly smaller than a sucrose-containing sample, which means that the molecules of sucrose bind strongly to the L-lysine in comparison to glucose resulting in higher density for sucrose-containing sample. The density of the sample contained salts were found to be higher than the L-lysine itself while smaller than those obtained for the samples containing sucrose and glucose, which shows that there was a weak interaction between salts and L-lysine (Figure 2).

The increase in density with the concentration of L-lysine in an aqueous solution of salts suggests a solute-solvent interaction exists between the electrolyte and water. Density data provides interesting information regarding the ion-ion, ion-solvent, and solvent-solvent interaction and also on the structural effect of solute and solvent in the solution.

The conductance data has shown in table and Fig. 4. The conductance was increased with the concentration of L-lysine. It is because the conductivity changes with the concentration of the electrolyte. The number of ions per unit volume carrying the current decreases on dilution, so conductivity always decreases with a decrease in concentration and increases with an increase in concentration. Greater the number of ions in the solution the greater is the conductance. The strong electrolytes (NaCl and KCl) dissociate almost completely into ions in solution and therefore their solutions have high conductance. The conductance of the samples was in the order of L-lysine + NaCl > L-lysine + KCl > L-lysine > L-lysine + sucrose > L-lysine + glucose¹⁷. The conductance of solution containing NaCl was highest in comparison to all because NaCl is a strong electrolyte and dissociates completely in an aqueous solution. The amino acid has a number of free amino groups and when NaCl solution was mixed then the numbers of free ions increase resulting increase in conductance. The conductance of samples containing KCl was slightly smaller than those obtained for samples contained NaCl due to weak dissociation than NaCl but higher than L-lysine itself. On the other hand, the conductance of the aqueous solutions of L-lysine with glucose was smaller than those obtained for L-lysine itself. This is because of the non-electrolytic nature of glucose and also the presence of Maillard reaction where free amino groups of L-lysine react with reducing sugar (glucose) resulting in less number of ions present in solution and hence decrease in conductance¹⁷. The conductance of sucrose was slightly smaller than L-lysine but higher than those obtained for L-lysine + glucose solution because sucrose is a non-reducing sugar and does not participate in the Maillard reaction.

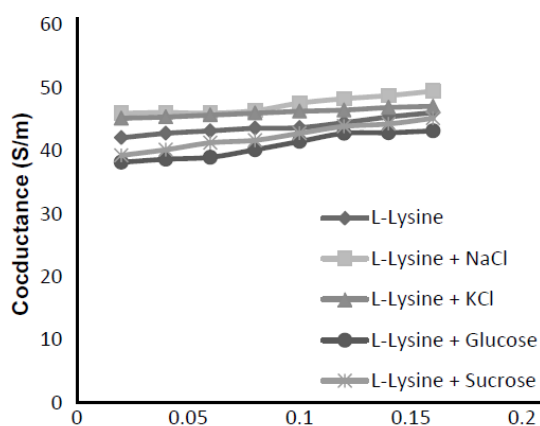


Fig. 4. Conductance versus concentration of L-Lysine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K

Table 1: The viscosity (ρ), surface tension (γ), density (η), and the specific conductance (κ) at 293.15K

M (mole/L)	ρ (g/cm ³)	γ (dyne/cm ²)	η (mpa.S)	κ (S/m)
		L-lysine		
0.02	0.61	65.16	0.69	42.1
0.04	0.61	66.79	0.69	42.8
0.06	0.62	67.82	0.73	43.2
0.08	0.63	70.76	0.74	43.6
0.1	0.63	72.62	0.75	43.7
0.12	0.64	73.77	0.78	44.5
0.14	0.65	74.92	0.79	45.4
0.16	0.65	76.95	0.81	46.1
		L-lysine + NaCl		
0.02	0.63	61.32	0.72	46
0.04	0.64	65.19	0.73	46.1
0.06	0.65	66.21	0.75	46
0.08	0.65	67.79	0.76	46.4
0.1	0.67	69.87	0.78	47.6
0.12	0.67	69.87	0.78	48.3
0.14	0.7	74.78	0.83	48.8
0.16	0.71	79.74	0.86	49.5
		L-lysine + KCl		
0.02	0.65	64.71	0.75	45.2
0.04	0.66	67.23	0.76	45.4
0.06	0.66	68.83	0.77	45.7
0.08	0.67	68.83	0.79	46
0.1	0.68	72.64	0.81	46.3
0.12	0.68	74.46	0.82	46.5
0.14	0.69	75.55	0.84	46.9
0.16	0.71	79.74	0.87	47.1
		L-lysine + glucose		
0.02	0.67	66.69	0.79	38.2
0.04	0.67	66.69	0.81	38.7
0.06	0.68	69.27	0.82	39
0.08	0.69	71.96	0.84	40.2
0.1	0.71	74.05	0.87	41.5
0.12	0.71	75.84	0.87	42.8
0.14	0.72	76.91	0.88	42.9
0.16	0.73	79.94	0.90	43.2
		L-lysine + sucrose		
0.02	0.69	70.29	0.79	39.3
0.04	0.69	70.29	0.81	40.2
0.06	0.7	73.00	0.83	41.3
0.08	0.71	74.05	0.86	41.7
0.1	0.71	75.84	0.85	42.8
0.12	0.73	79.94	0.89	43.9
0.14	0.74	81.03	0.92	44.3
0.16	0.74	83.11	0.91	45.2

CONCLUSION

In this study, we have studied the interaction of glucose, sucrose, sodium chloride, and potassium chloride with the L-lysine at different concentrations. The viscosity (η), surface tension (γ), density (ρ), and the specific conductance (κ) measurements have been carried out for amino acid L-lysine, L-lysine in aqueous glucose, sucrose, sodium chloride,

and potassium chloride at 293.15K for different concentrations. The experiments show that there was an increase in the viscosity, surface tension, conductance, and density of the amino acid with an increase in the concentrations of L-lysine. And also there was an increase in the viscosity (η), conductance (κ), surface tension (γ), and density (ρ) with an increase in the concentration of L-lysine in glucose, sucrose, NaCl, and KCl. The density

was maximum for the aqueous solution of L-lysine + sucrose and minimum for the L-lysine solution due to the solute-solvent interaction. We have found that the viscosity of the sample containing sucrose is highest in comparison to all and smallest for L-lysine and surface tension of the sample of sucrose is highest in comparison to all and smallest for sample contained NaCl solution. The conductance of the samples was in the order of L-lysine + NaCl > L-lysine + KCl > L-lysine > L-lysine + sucrose > L-lysine + glucose.

This study could be useful in various industries like food, pharmaceutical, cosmetic, etc.

ACKNOWLEDGMENT

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors declare no conflict of interest.

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