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Assessment of Salts Effect in Sugar-aqueous System

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ABSTRACT

In the present study, the preferential salvation of salts in sugar-aqueous systems has been considered. It is carried out by using conductometric observation of analytical grade sugar and plantation white sugar aqueous system with salts viz. $CaCl_2$, $MgCl_2$, KCl, NaCl. It shows that the conductivity is in a linear relationship with the electrolytes and non-sugar present in both analytical grade sugar and plantation white sugar over a range of 5 to 25 W/V percent. The optimum range of concentration found to be for both the sugars is about 20%. Encouraging results could be obtained in the determination of sugars i.e. non-electrolytes and electrolytes in aqueous sugar solution products. The present study shows valid technological interest to understand the Maillard reaction due to the adoption of $MgCl_2$ salt in place of sulphite. These sugars–salts complexes are responsible for the formation of molasses which leads to substantial loss of sugar of around ten percent of the total sugar present in cane.

Keywords: Conductivity, Electrolytes, Non-sugars, Analytical grade sugar, Plantation white sugar, salts.

INTRODUCTION

Assessment of sugar quality is carried out by using conventional parameters like Brix, Pol, and Purity. These conventional parameters are calibrated in terms of pure sucrose solution, ignoring non-sugars substances having importance during cane sugar manufacture. Apart from these parameters, conductivity has a direct bearing on the quantity of non-sugars[1-3]. A lower conducting sugar has a more saleable appeal than one which is higher conductivity due to inclusion of impurities in the form of mineral constituent's, organic non-sugars & insoluble impurities present in cane juice Table 1, or may form during sugar processing like carbonation, phosphotation, and sulphitation[4]. In India, plantation white sugar is directly produced from cane juice having many impurities. These impurities like inorganic salts do affect solubility and crystallization rate of sucrose[5]. The complexities of interactions between water, sugar, and eventually impurities in supersaturated solutions have been demonstrated earlier[6-8]. Knowledge of composition regarding these non-sugars as impurities with special reference to selected salts ($CaCl_2$, $MgCl_2$, KCl, NaCl) is used in this study through the conductivity method, because they affect sugar manufacturing process such as sucrose hydrolysis & sugar crystallization[9-11]. The development of a new approach for inhibiting the Maillard reaction employing additive such as $MgCl_2$ in sucrose in place of sulphite has a valid technological interest. The effect of cations which is produced from $CaCl_2$, $MgCl_2$, KCl, NaCl, can be analyzed through electrolytes- non-electrolytes interaction, which modulate the kinetic of Maillard reaction[12].

In recent years, Nuclear Magnetic Resonance is one of the useful technique for analyzing the water mobility in food products[13]. NMR techniques require lots of technical skill. Initially, the mobility of water in the sucrose solution used to be checked by conductivity method[14]. The study of the interaction of salts with sucrose solution by the proposed conductivity method is explained based on ion–solvent, solvent–solvent, and ion-ion interaction, present in solution[15-18].

Multivalent electrolytes in aqueous sugar solution constitute an almost unexplored field. So the conductivity analyses of these inorganic non-sugar electrolytes in analytical grade sugar, as well as Indian sugar, have been carried out by taking 5 to 25% w/v concentration.

The aim of the present investigation is to find out the actual concentration of both analytical grade sugar as well as plantation white sugar where deviation in linearity occurs in the presence of selected salts. Study reveals that deviation in linearity for conductivity values occurs at around 22.5% w/v of sugar solution.

MATERIALS AND METHOD

The Shimadzu AW 320 balance was used for the weightiest of sugars and inorganic salts. Analytical grade sugar was purchased from Merck (Mumbai) India, and white sugar was obtained from Indian Sugar manufacturers with different grain sizes.

A glass cell (Vol. 30 cm^3) with a platinum electrode was used for conductivity measurement (μS/cm). Two sets of experiments were performed, one at isothermal condition (298.15K), and the other at experimental temperature (298.15 K-373.15K). The temperature of the supercooled solution was controlled by ethylene water bath. Aqueous KCl solution (0.01M) was used for cell calibration. Double distilled water was used to prepared sugar solution.

The experiment results were given as the mean of five parallel trail and measurements. Analysis of variance and Duncan's multiple range tests were employed to statistically analyze all results. A statistical data analysis software system (Stat Soft, Inc. version 6.2001) was used for analysis. P value<0.05 was regarded as significant.

RESULTS & DISCUSSION

Various impurities such as salts Table 1, dextran, and invert sugars affect the sugar crystallization rate. Although, a detailed mechanism of impurity transfer during crystallization is not discussed in the literature.

In the first series of experiments, the blank value i.e. the solution containing the same concentration of salts (0.01M) as in the above experiment and with no sugar was observed. The variations of concentration of salts were, however, limited by the solubility of the salt under examination. However, it was in the range of 0.0025–0.01 molar concentration. Fig. 1 shows the percent rise in conductivity values of NaCl & KCl is around 73%, whereas in the case of $CaCl_2$, $MgCl_2$ it is to be 76%.

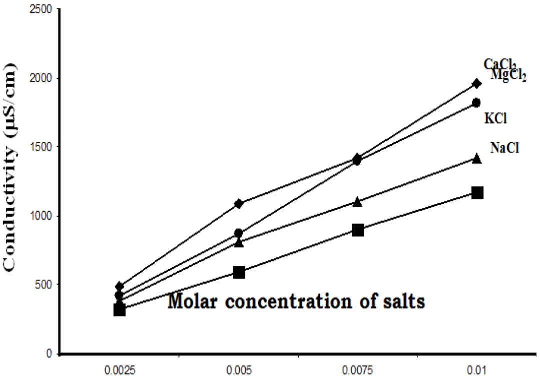

Fig. 1. Molar conductivity of salts

Table 1: Salts Concentration in Cane Juice

Components (cationic)	Salts	Concentration (% Brix)	Molar Concentration
K_2O	KCl	0.67-1.21	0.6316
Na_2O	NaCl	0.01-0.03	0.0068
CaO	$CaCl_2$	0.24-0.48	0.2016
MgO	$MgCl_2$	0.10-0.39	0.096

In the second series of experiments, the effect of inorganic salts on the electrical conductivity of analytical grade sugar as well as plantation white sugars was carried out. For this purpose, standard solutions of the mentioned salts were prepared for making the molar concentration of salts. It may be pointed out that all the inorganic salts examined viz. $CaCl_2$, $MgCl_2$, KCl, NaCl) were found as inhibiting the electrical conductivity of the sucrose solution. For a known concentration of sugar, the influence of salts on the electrical conductivity shows an increasing trend in both the case i.e. analytical reagent as well as plantation white sugar.

A comparative study was carried out to assess the conductivity of various alkaline earth metals in distilled water is summarized in Fig. 1. Only $CaCl_2$ was found to generate a sufficient amount of electrical conductivity to be monitored by electrical conductivity meter of 0.01 molar concentration ranges in analytical grade sugar as well as plantation white sugar at room temperature, and salts like $MgCl_2$ Fig. 2. Further, to this, from Fig. 2, one can get the following series indicating the effect of inorganic salt components on the electrical conductivity of sugars i.e. Ca^{++}> Mg^{++}.

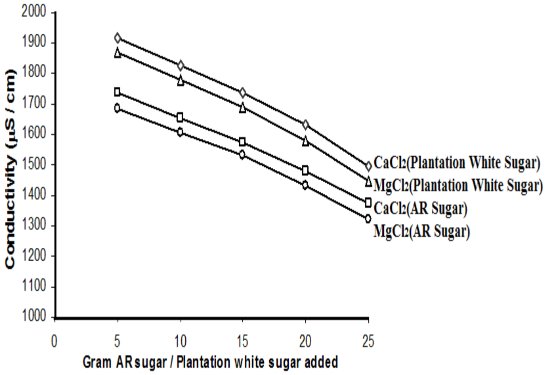

Fig. 2. Sugar Vs Bivalent salts conductivity

Further, from Fig. 3 it is evident that the series indicates the effect of inorganic salt components on the electrical conductivity of analytical grade sugar solution as K^+>Na^+. Similar data were obtained at the same concentration of plantation white sugar solution having slightly higher values than analytical grade sugar due to more impurities adhering in plantation white sugars. The observation for KCl and NaCl are represented graphically in Fig. 3. On the other hand, the complex formed between sugar and univalent metallic salts like KCl and NaCl etc are unimolecular types. This is of marked importance and suggests that in a mixture of a sugar and univalent metallic salts complex formation takes place as a result of one molecule of sugar and one molecule of salt. The complexes may be represented as $C_{12}H_{22}O_{11}$, KCl & $C_{12}H_{22}O_{11}$ NaCl etc in accordance with the data obtained in crystallization and phase rule studies.

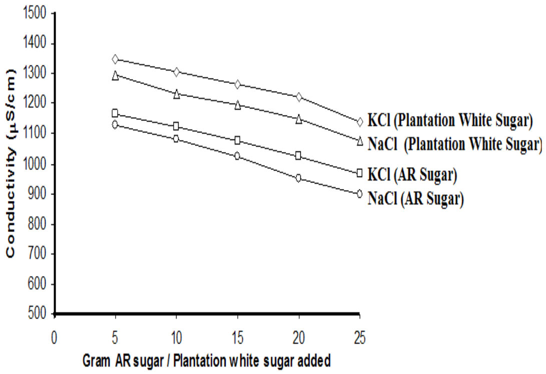

Fig. 3. Sugar Vs Univalent salts conductivity

Exact measurement of inorganic salts as an impurity is mentioned at a known concentration of sugar solution in the present analysis by conductivity method to specify the salts generating higher effect on crystal growth as found in the order of Ca^{++}> Mg^{++}> K^+> Na^+.

Further to this, Fig. 2 & 3 shows that the deviation in linearity of conductivity values of both the sugars occurs at 20 gram/volume concentration, whereas at higher concentration than 20% gram/ volume linearity deviates. It is due to that in sugar–salts system a micellar colloid is formed and volatiles substances are entrapped. By observing electrical conductivity of sugar solution it suggests that the micellar colloid beyond this concentration forms at a maximum degree hence our observation for 22.5% w/v proves to be appropriate. So the analysis would be helpful within this concentration. The observed results are having good agreement with previous work[19-20]. Similar work on calcium chloride, affecting the sugar crystal growth is already mentioned in literature[3] showing that impurity act on the properties of the solution is controlled by conductivity measurement.

Impurity measurement in sugar solution during batch crystallization, conductivity analysis would be helpful, and more importantly the pH which is practically ignored in this analysis due to some obvious reason as mentioned earlier[1-2]. Literature also reveals that the conductivity of the solution depends upon several variables such as salts, and temperature.

The elucidating part of this study reveals that the complex formation occurs between sugar and inorganic salts causes a dip in electrical conductivity value. The charge transfer reaction occurs in sugar–water–salts system. Finally a similar picture of ion–water interactions has been reached by a quite different approach[21]. This can be more or less than the exchange time for molecules in pure water. The values of this ratio for the above-analyzed salts are given in Table 2.

Table 2: Hydration Number of Salts

Constituents (cationic)	Average time	Hydration Number
Na^+	1.46	7-9
K^+	0.65	4
Mg^{++}	86.3	12-14
Ca^{++}	2.16	9-12

Moreover, it is based on a study that the ion association would be less in case of univalent anion, and this generally true; there is no evidence of ion pairing in the halides of sodium and potassium hence record lesser conductivity value in comparison with alkaline earth metals i.e. calcium and magnesium. Here the metal of higher atomic number shows more ion pairing, as in the halide. It is interesting to note that ion pairing is directly proportional to the atomic radius. Data is available in the literature for the group II metals, and with the increase in cationic charges, the formation of ion pairs in dilute solution becomes the rule rather than the exceptions Table 2.

CONCLUSION

The present study reveals that the conductivity parameter can be utilized to measure the impurity in sugar solution in terms of its concentration at around 20% W/V. The conductivity value can be assumed as a function of impurity concentration (C impurity) and sugar concentration (C sucrose) as a similar finding is available in literature. The Maillard reaction due to the adoption of magnesium chloride and not sulphite is another fact-finding interpretation of the present study.

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Conflicts of Interest

The authors declare no conflict of interest.

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