SUGAR SOLUBILITY

Sucrose and Dextrose in Aqueous Glycerol

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Glycerol and sucrose or dextrose are often used together in cake icings, candies, sirups, and pharmaceutical elixirs. In planning a recipe or formula that will prevent or promote crystallization of the sugar, as the need may be, it is important to know the solubility of the sugar. Solubilities of sucrose in several concentrations of aqueous glycerol were determined at 15° and 35° C. Solubilities of dextrose were determined at 15°, 25°, and 35° C. Sucrose is more soluble than dextrose at lower glycerol concentrations but dextrose is the more soluble at higher glycerol concentrations. The solubility of both sugars is decreased by increased glycerol concentration and by lowered temperature.

GLYCEROL IS USED AS A HUMECTANT, to improve the texture and consistency of candies, icings, and sirups, and in pharmaceutical elixirs and cough sirups. It is desirable to know the solubilities of the common sugars, sucrose and dextrose, in aqueous glycerol at ordinary temperatures in order that crystallization may be prevented or promoted, as the need may be. Sucrose solubilities at 15° and 35° C. and dextrose solubilities at 15°, 25°, and 35° C. are reported. Sucrose solubility at 25° C. has been previously reported (*3*). Glycerol concentrations of from 25 to 95% by weight were used.

Materials

Glycerol, U.S.P. grade. 95% weight concentration, Armour and Co., Chicago, Ill.

Sucrose, C.P. 99.9+%, specific rotation 66.5°, Pfanstiehl Chemical Co., Waukegan, Ill.

Dextrose, C.P. anhydrous. 99.9+% (special sample) Corn Products Refining Co., Argo, Ill.

Water, distilled

Apparatus and Procedure

The solutions were prepared in 100-ml. serum vials (No. 14200 Kimble Brand; Owens-Illinois Glass Co.) closed with sleeve stoppers (No. 17 sleeve stoppers, No. 73 red; West Co., Inc., Phoenixville, Pa.). The bottles (vials) were held on a homemade reel with a capacity of eight bottles, which was immersed in a constant temperature bath and rotated at about 12 r.p.m. by a chain drive from a small gear-head motor. The bath temperature was constant within ±0.05° C. The sugar content of the solutions was measured with a Fric saccharimeter having a Ventzke scale. Specific gravities of the solutions were measured in 25-ml. pycnometers, and refractive indices with an Abbé refractometer.

Experimental

Glycerol-water solutions of 25.0, 50.0, 62.5, 75.0, 82.5, and 95.0 weight % glycerol content were prepared. Their compositions were established from their specific gravity measurements, using the data of Bosart and Snoddy (*2*).

To prepare a sugar-saturated solution, the aqueous glycerol solvent and slightly less than the estimated quantity of sugar to make about 90 ml. of solution were weighed into a bottle and kept in the constant temperature bath until the sugar had dissolved. More sugar was added in 1-gram portions until about 0.5 gram (visually estimated) remained undissolved. The refractive index of the solution was then measured at 25° C. at daily intervals. When it remained constant 4 days for solutions held at 25° or 35° C., or 7 days for solutions at 15° C., the solution was assumed to be

Table I. Solubility of Sucrose in Aqueous Glycerol at 15°, 25°, and 35° C.

Solvent	Sucrose, Grams/100 Ml. Solution			Sucrose, % by Weight		
	15° C.	25° C. (3)	35° C.	15° C.	25° C. (3)	35° C.
Water	87.9 (*1*)	90.6 (*1*)	93.4 (*1*)	66.3	67.89	69.5
Glycerol, wt. %						
25.0	73.2	78.2	82.2	55.9	59.4	61.9
50.0	54.6	58.0	63.7	42.4	44.8	48.7
75.0	28.8	32.4	38.1	22.7	25.4	29.5
82.5	20.1	25.5	29.9	15.9	20.0	23.3
95.0	5.8	12.6	16.6	4.6	9.9	13.0
99.96	..	7.2	..	..	5.7	..

Table II. Specific Gravity and Refractive Index of Aqueous Glycerol Saturated with Sucrose

Solvent	Temp. at Saturation			Temp. at Saturation		
	15° C.	25° C. (3)	35° C.	15° C.	25° C. (3)	35° C.
	Specific Gravity 25/25° C.			n_D^{35}		
Water	....	1.3347 (*1*)	1.3441 (*1*)	....	1.4607	1.4633
Glycerol, wt. %						
25.0	1.3099	1.3175	1.3286	1.4540	1.4571	1.4610
50.0	1.2884	1.2963	1.3077	1.4530	1.4564	1.4599
75.0	1.2688	1.2756	1.2894	1.4570	1.4610	1.4639
82.5	1.2627	1.2751	1.2835	1.4600	1.4640	1.4666
95.0	1.2657	1.2744	1.2812	1.4700	1.4723	1.4743
99.96	....	1.2758	....	....	1.4796	....

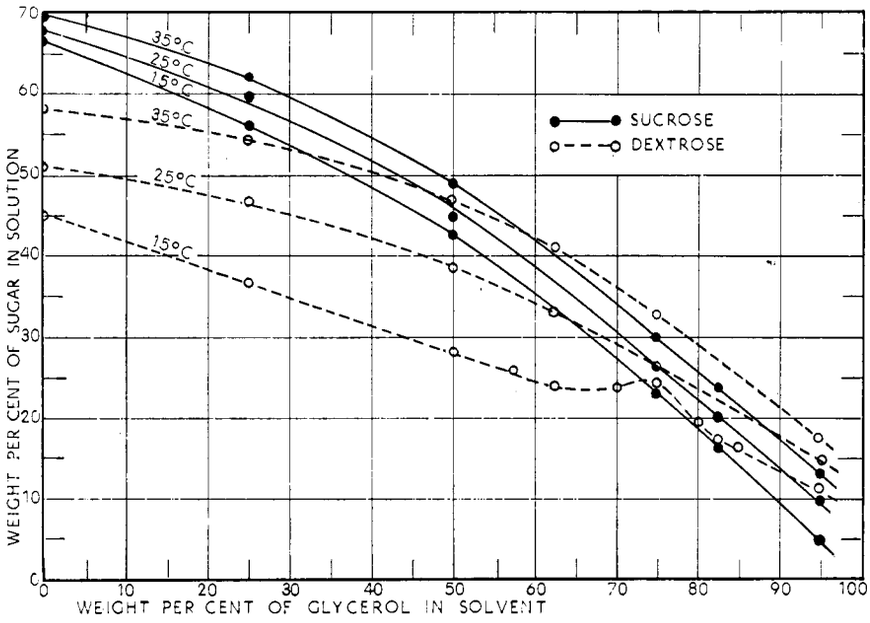

Figure 1. Solubility of sucrose and dextrose in aqueous glycerol at 15°, 25°, and 35° C.

saturated. The longer time of observation at 15° C. was adopted because equilibrium was reached very slowly at this temperature, especially in solutions containing the higher concentrations of glycerol. After saturation was attained, the solutions were kept in the constant temperature bath without agitation.

Saturated sucrose solutions were prepared without difficulty. To measure the sucrose concentration, about 10 ml. of the solution was accurately weighed in a 50-ml. volumetric flask and diluted to volume. The optical rotation of the solution was then measured at 20° C. in the saccharimeter and the sugar content calculated from published tables (*1*). (It has been shown that the presence of glycerol has no effect upon the optical rotation of sugar solutions, *3*.) Specific gravity at 25/25° C. and index of refraction, n_D^{25}, of the saturated solutions were measured. Compositions of the solutions are given in Table I and Figure 1. Specific gravity and refractive index data are in Table II.

Saturated dextrose solutions were prepared from anhydrous dextrose at 15°, 25°, and 35° C. Dextrose is available in two pure crystalline forms, anhydrous dextrose and dextrose monohydrate. In saturated simple water-dextrose solutions, the monohydrate is the stable solid phase below 50° C., the anhydrous dextrose above 50° C. Addition of glycerol to the solution lowers the transition temperature, so that with more than 50 or 60% of glycerol in the solvent, anhydrous dextrose is the stable solid phase at ordinary temperature. Anhydrous dextrose was used to avoid adding unwanted water to the solution. The excess of undissolved dextrose was kept below about 0.5 gram per 100 ml. of solution to minimize the amount of water that might be withdrawn from the solution by the formation of dextrose hydrate.

Concentration of the dextrose, specific gravity, and refractive index of the solutions were measured in the same manner as for the sucrose solutions. The composition data are given in Table III and Figure 1, and the specific gravity and refractive index data are given in Table IV.

Dextrose solutions saturated at 25° and 35° C. were prepared without difficulty. Repeated attempts were made to prepare dextrose solutions saturated at 15° C. Although solutions appeared to be saturated, in that no more dextrose would dissolve, analyses of the solutions did not give concordant results. Preparing supersaturated solutions and, allowing them to come to apparent equilibrium at 15° C. did not produce better results. It appears very difficult to attain equilibrium in these solutions.

The data on concentration of dextrose in solutions saturated at 15° C. are the averages of several determinations, and, although the results of the individual determinations are scattered, are believed to give a fair approximation of the correct values. The specific gravity and refractive index data for these solutions do not have precision equal to that of corresponding data for the other solutions.

The graph of the solubility data for dextrose at 15° C. has a hump at 75% glycerol concentration, indicating an increase in dextrose solubility within a certain range of increasing glycerol concentration. Such an effect was not found at higher temperatures or with sucrose. Because of the irregular shape of the curve, solubility determinations were repeated several times and made

Table III. Solubility of Dextrose in Aqueous Glycerol

Solvent	Dextrose, Grams/100 Ml. Solution			Dextrose, % by Weight		
	15° C.	25° C.	35° C.	15° C.	25° C.	35° C.
Water	..	62.2 (*1*)	73.5 (*1*)	45.0 (*4*)	50.8 (*1*)	58.0 (*1*)
Glycerol, wt. %						
25.0	44.1	58.0	70	36.4	46.5	54.5
50.0	34.1	47.9	62.2	27.8	38.1	46.6
57.5	31.3	..	..	25.3	..	..
62.5	29.4	41.7	52.8	23.6	33.0	40.9
70.0	30.1	..	..	23.2	..	..
75.0	30.4	32.5	41.8	24.1	25.6	32.5
80.0	24.1	..	..	19.0	..	..
82.5	21.3	..	..	16.8	..	..
85.0	20.3	..	..	16.0	..	..
95.0	13.9	18.2	22.2	10.9	14.3	17.3

Dextrose concentrations calculated as anhydrous dextrose, $C_6H_{12}O_6$.

Table IV. Specific Gravity and Refractive Index of Aqueous Glycerol Saturated with Dextrose

Solvent	Temp. at Saturation			Temp. at Saturation		
	15° C.	25° C.	35° C.	15° C.	25° C.	35° C.
	Specific Gravity 25/25° C.			n_D^{25}		
Water	....	1.2237 (*1*)	1.2667 (*1*)	....	1.4230 (*1*)	1.4408 (*1*)
Glycerol, wt. %						
25.0	1.212	1.2481	1.2836	1.416	1.4323	1.4463
50.0	1.226	1.2583	1.2915	1.432	1.4430	1.4541
57.5	1.236	....	....	1.439	....	....
62.5	1.245	1.2647	1.2918	1.443	1.4503	1.4587
70.0	1.243	....	....	1.444	....	....
75.0	1.263	1.2673	1.2869	1.455	1.4570	1.4636
80.0	1.266	....	....	1.460	....	....
82.5	1.266	....	....	1.461	....	....
85.0	1.269	....	....	1.464	....	....
95.0	1.271	1.2723	1.2833	1.472	1.4711	1.4740

with more glycerol concentrations than were used in the rest of the work. Although the authors have no explanation for this abnormal solubility effect, they have enough supporting data to be convinced that it is real and not merely a consequence of experimental error.

The tightness of the sleeve stoppers of the solution bottles was demonstrated by making Karl Fischer moisture determinations on four samples that had been immersed in the constant temperature bath for 46 days at 15° C. After deducting the dextrose, as determined with the saccharimeter, the water content of the solvent was found to be unchanged.

Sample	*a*	*b*	*c*	*d*
Original water concentration, %	75.1	49.9	37.4	25.1
Water by analysis after 46 days, %	75.0	51.1	37.65	25.0

Acknowledgment

The pure dextrose used in this work was generously supplied by George R. Dean, Corn Products Refining Co.

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Received for review April 13, 1953. Accepted June 22, 1953. Work sponsored by the Glycerine Division, Association of American Soap and Glycerine Producers, New York, N. Y.

ENZYME INACTIVATION

Relation of Rates of Inactivation of Peroxidase, Catecholase, and Ascorbase to Oxidation of Ascorbic Acid in Potatoes and Parsnips

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This study was undertaken to show whether the rate of enzyme inactivation could be correlated with ascorbic acid retention in cooked foods. Potatoes and parsnips were heated to various internal temperatures between 25° and 90° C. Each temperature was attained by four methods of cooking—pressure-cooking, steaming, boiling, and baking. At each temperature, potatoes were assayed for catecholase activity and parsnips for ascorbase and peroxidase activities; ascorbic acid was determined in both vegetables at each temperature. Statistical analysis of the data indicated that pressure-cooking caused a more rapid rate of enzyme inactivation than did baking; steaming and boiling caused intermediate rates which did not differ significantly from each other. The rate of enzyme inactivation, however, could not be related to the amount of ascorbic acid retained in either cooked potatoes or parsnips.

TWO TYPES OF OXIDATION OF ASCORBIC ACID in foods account for losses of this nutrient—autoxidation, catalyzed chiefly by copper but also by other metals and by metal complexes; and enzymatic oxidation, catalyzed by peroxidase, polyphenolases, ascorbase, and the cytochrome system. This study is concerned with the enzymatic oxidation of ascorbic acid in potatoes and parsnips during cooking.

The role of enzymes in relation to ascorbic acid retention has been investigated in cooked vegetables, in various fruits which show discoloration on injury, and in fruits and vegetables prepared for freezer storage (*1, 5, 8*). Green beans blanched for varying lengths of time at a low temperature retained less ascorbic acid than did similar beans blanched at higher temperatures (*2*). In experiments in which the enzyme activities and ascorbic acid content of various vegetables were determined before and after blanching for three different periods, and after freezer storage for varying lengths of time, no relationship was shown between enzyme activity and vitamin content of the frozen vegetables (*3*).

The present study is concerned with the difference in the rates of enzyme inactivation resulting from cooking potatoes and parsnips by various methods, and the relationship between rates of enzyme inactivation and retention of ascorbic acid. In this study the following have been determined: the catecholase activity of potatoes, the ascorbase and peroxidase activities of parsnips, and the ascorbic acid content of both vegetables cooked to various internal temperatures. As the cytochrome system is not an important terminal oxidase system in plants (*4*), it has not been considered in this study. The cooking methods for both vegetables were pressure-cooking, steaming, boiling in a covered saucepan, and baking.

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Experimental Methods

Selection and Storage Of Vegetables Potatoes were purchased in two lots. Bliss Triumph redskin potatoes were obtained on the day of harvest from a Gary, Ind., potato farm in October 1951 and tested during the following 3 months. The second lot consisted of South Dakota redskins that were purchased in February 1952 from a local Chicago market; these were assayed in the following 2 months. Parsnips harvested the previous autumn were obtained from a local wholesale market in Chicago in May 1952, and all determinations with parsnips were completed by July 1952. Upon delivery to the laboratory, the vegetables were sorted by size and weight, and were stored at 10° C. until the time of assay.