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ACCURATE COMPILATION OF BRIX, APPARENT SPECIFIC GRAVITY, APPARENT DENSITY, WEIGHT, AND POUNDS SOLIDS OF SUCROSE SOLUTIONS

C. S. CHEN
Florida Department of Citrus,
700 Experiment Station Road,
Lake Alfred, FL 33850

Abstract. **On the basis of 2 official tables of Brix and density data, new tables of °Brix and pounds solids were prepared by the author by using computerized techniques. Extension of such techniques to retain the numbers at the best available accuracy is illustrated. A table for some selected °Brix values is presented.**

An application of the table to investigate the effect of one tenth of one °Brix measurement errors revealed that the variation of cost of solids would amount to ± 5.3 million dollars for the citrus juices sold in 1981-82 season. In view of the importance of °Brix measurements, the most accurate and reliable instrument should be used to ensure the correctness of °Brix measurement in citrus processing plants.

More than a hundred million boxes of citrus fruits were used by the processors annually in the last 15 yr. Citrus fruits used for processing are sold in 2 ways; pounds-solids or pounds of juice per box. Both require the information on pounds solids contained in the fruits. Tables of °Brix and pounds solids have been prepared by several authors (1, 2, 4). The accuracy for those available publications are more than sufficient for technical as well as practical purposes. However, for accurate determination of total solids in several million gallons, slight discrepancies will be found dependent upon which table is used. Such discrepancies are resultant mostly from truncating the calculated numbers to 3 or 4 decimals for ordinary use in practice. A few minor conversion errors have also been found in tables prepared manually.

This paper presents a new table for pounds solids of sucrose up to 5 decimals for some selected °Brix values. Computerized calculations and print-outs were used to eliminate the human errors. This is an illustration of the method used by the author in a recent publication of new Brix-pounds solids tables (2).

Materials and Methods

°Brix, apparent specific gravity, and apparent density in g/liter were taken from 2 official tables adopted by the Florida citrus industry: Table 114 (5) and Table 1 (6).

The density data for each correspondent °Brix was used to convert to other units or other derived quantities. The data for 12°Brix will be arbitrarily selected to illustrate the calculations.

Denote the °Brix (or percent solids by weight) by B and apparent density (or weight per liter in air at 20°C) by D. Then solids weight, denoted by W, is equal to

$$W = (B \times D)/100$$

For B = 12°Brix and D = 1045.41 g/liter then $W = \frac{12}{100} \times 1045.41 = 125.449$ g/liter.

The apparent density expressed in pounds per U.S. gallon (1 g/liter = 1/119.827 lb./gal) in air at 20°C, denoted by D_1, was calculated by

$$D_1 = D/119.827 \text{ lb./gal.}$$

For B = 12°Brix and D = 1045.41 g/liter then

$$D_1 = 1045.41/119.827 = 8.72432 \text{ lb./gal.}$$

The solids weight, denoted by W_1, is equal to

$$W_1 = (B \times D_1)/100$$

For B = 12°Brix, and D_1 = 8.72432 lb./gal. then

$$W_1 = \frac{12 \times 8.72432}{100} = 1.04692 \text{ lb./gal.}$$

The apparent density expressed in pounds per cubic feet (1 g/liter = 0.062428 lb./ft³) in air at 20°C, denoted by D_2, was calculated by

$$D_2 = D \times 0.062428 = 65.2628 \text{ lb./ft}^3.$$

The solids weight, denoted by W_2, is equal to

$$W_2 = (B \times D_2)/100.$$

For B = 12°Brix and D_2 = 65.2628 lb./ft³ then

$$W_2 = \frac{12 \times 65.2628}{100} = 7.83154 \text{ lb./ft}^3.$$

A computer program was written to carry out the computation for °Brix varying from 0 to 80 °Brix at 0.1°Brix intervals. The corresponding density data were taken from the official tables. The derived data were printed out from the computer without transcription so that human errors were avoided. Only selected ranges of °Brix are shown.

Results and Discussion

Table 1 shows the results of computation. To use the table, find the Brix value that corresponds to the actual measurement, then trace the line to the right to read the number under the desired heading in the top line of the table. The figure so obtained will show the computed number. For example, 41.8°Brix concentrate will have 4.13266 lb. solids/gal in air.

For technical or practical purposes, retention of 6 significant digits is not necessary. Four to 5 digits retention have been reported in the literature (1, 2). However, for large quantity calculation, the best available accuracy would be desirable.

For example, a plant has packed one million gallons of reconstituted juices at 11.9°Brix instead of required 11.8 °Brix. How much additional juice cost will be required at the solids cost of $1.22 per pound?

From Table 1, we find solids weight 1.03778 lb./gal at 11.9°Brix and 1.02864 lb./gal at 11.8°Brix. The difference between the two is 0.00914 lb./gal. For one million gallons, the additional cost will be

$$\text{Additional cost} = 0.00914 \times 1{,}000{,}000 \times 1.22 = \$11{,}150.80.$$

This example illustrates the importance of tight quality control for process operations.

The effect of °Brix measurement errors varies with the level of solids content. Errors at the lower °Brix level will have greater effect than that of the higher °Brix level. For

Table 1. Table of Brix, apparent specific gravity, weight, and solids weight of sucrose solutions.

°Brix or % by wt. sucrose	Apparent specific gravity 20/20°C	Wt./liter in air at 20°C (g)	Sucrose/liter in air (g)	Wt./gal in air at 20°C (lb.)	Sucrose/gal in air (lb.)	Wt./ft³ in air at 20°C (lb.)	Sucrose/ft³ in air (lb.)
6.0	1.02369	1020.80	61.248	8.51894	0.51114	63.7265	3.8236
6.5	1.02571	1022.81	66.483	8.53572	0.55482	63.8520	4.1504
7.0	1.02773	1024.83	71.738	8.55258	0.59868	63.9781	4.4785
7.5	1.02976	1026.85	77.014	8.56944	0.64271	64.1042	4.8078
8.0	1.03180	1028.88	82.310	8.58637	0.68691	64.2309	5.1385
8.5	1.03385	1030.93	87.629	8.60348	0.73130	64.3589	5.4705
9.0	1.03590	1032.97	92.967	8.62051	0.77585	64.4862	5.8038
9.1	1.03631	1033.38	94.038	8.62393	0.78478	64.5118	5.8706
9.2	1.03672	1033.79	95.109	8.62735	0.79372	64.5374	5.9374
9.3	1.03713	1034.20	96.181	8.63077	0.80266	64.5630	6.0044
9.4	1.03755	1034.61	97.253	8.63420	0.81162	64.5886	6.0713
9.5	1.03796	1035.03	98.328	8.63770	0.82058	64.6148	6.1384
9.6	1.03837	1035.44	99.402	8.64112	0.82955	64.6404	6.2055
9.7	1.03879	1035.85	100.477	8.64454	0.83852	64.6660	6.2726
9.8	1.03920	1036.26	101.554	8.64797	0.84750	64.6916	6.3398
9.9	1.03961	1036.67	102.630	8.65139	0.85649	64.7172	6.4070
10.0	1.04003	1037.09	103.709	8.65489	0.86549	64.7434	6.4743
10.1	1.04044	1037.50	104.787	8.65831	0.87449	64.7690	6.5417
10.2	1.04086	1037.91	105.867	8.66173	0.88350	64.7946	6.6091
10.3	1.04127	1038.33	106.948	8.66524	0.89252	64.8208	6.6765
10.4	1.04169	1038.74	108.029	8.66866	0.90154	64.8464	6.7440
10.5	1.04210	1039.16	109.112	8.67217	0.91058	64.8727	6.8116
10.6	1.04252	1039.57	110.194	8.67559	0.91961	64.8983	6.8792
10.7	1.04293	1039.99	111.279	8.67909	0.92866	64.9245	6.9469
10.8	1.04335	1040.40	112.363	8.68252	0.93771	64.9501	7.0146
10.9	1.04377	1040.82	113.449	8.68602	0.94678	64.9763	7.0824
11.0	1.04418	1041.23	114.535	8.68944	0.95584	65.0019	7.1502
11.1	1.04460	1041.65	115.623	8.69295	0.96492	65.0281	7.2181
11.2	1.04502	1042.07	116.712	8.69645	0.97400	65.0543	7.2861
11.3	1.04544	1042.48	117.800	8.69987	0.98309	65.0799	7.3540
11.4	1.04585	1042.90	118.891	8.70337	0.99219	65.1061	7.4221
11.5	1.04627	1043.32	119.982	8.70688	1.00129	65.1324	7.4902
11.6	1.04669	1043.73	121.073	8.71031	1.01040	65.1580	7.5593
11.7	1.04711	1044.15	122.165	8.71381	1.01952	65.1842	7.6266
11.8	1.04753	1044.57	123.259	8.71732	1.02864	65.2104	7.6948
11.9	1.04795	1044.99	124.354	8.72082	1.03778	65.2366	7.7632
12.0	1.04837	1045.41	125.449	8.72432	1.04692	65.2628	7.8315
12.5	1.05047	1047.50	130.937	8.74177	1.09272	65.3933	8.1742
13.0	1.05259	1049.61	136.449	8.75937	1.13872	65.5250	8.5183
13.5	1.05470	1051.72	141.982	8.77699	1.18489	65.6568	8.8637
14.0	1.05683	1053.85	147.539	8.79476	1.23127	65.7897	9.2106
14.5	1.05897	1055.98	153.117	8.81254	1.27782	65.9227	9.5588
15.0	1.06111	1058.11	158.716	8.83031	1.32455	66.0556	9.9084
16.0	1.06542	1062.41	169.986	8.86619	1.41859	66.3241	10.6119
38.0	1.16853	1165.23	442.787	9.72427	3.69522	72.7430	27.6423
41.7	1.18754	1184.18	493.803	9.88241	4.12096	73.9259	30.8271
41.8	1.18806	1184.70	495.204	9.88675	4.13266	73.9584	30.9146
41.9	1.18858	1185.22	496.607	9.89109	4.14437	73.9909	31.0022
42.0	1.18910	1185.74	498.010	9.89543	4.15608	74.0233	31.0898
43.2	1.19539	1192.01	514.948	9.94776	4.29743	74.4148	32.1472
44.5	1.20226	1198.86	533.492	10.0049	4.45219	74.8424	33.3049
44.6	1.20279	1199.39	534.927	10.0093	4.46417	74.8755	33.3945
44.7	1.20332	1199.92	536.364	10.0138	4.47615	74.9086	33.4841
44.8	1.20385	1200.45	537.802	10.0182	4.48815	74.9417	33.5739
44.9	1.20438	1200.98	539.240	10.0226	4.50015	74.9747	33.6636
45.0	1.20491	1201.51	540.679	10.0270	4.51217	75.0078	33.7535
46.0	1.21026	1206.84	555.146	10.0715	4.63290	75.3406	34.6567
47.0	1.21564	1212.21	569.739	10.1163	4.75468	75.6758	35.5676
48.0	1.22106	1217.61	584.452	10.1614	4.87747	76.0129	36.4862
49.0	1.22652	1223.06	599.299	10.2069	5.00137	76.3532	37.4130
50.0	1.23202	1228.54	614.270	10.2526	5.12631	76.6953	38.3476
50.1	1.23257	1229.09	615.774	10.2572	5.13886	76.7296	38.4415
50.2	1.23313	1229.64	617.279	10.2618	5.15142	76.7639	38.5355
50.3	1.23368	1230.19	618.785	10.2664	5.16399	76.7982	38.6295
50.4	1.23423	1230.74	620.293	10.2710	5.17657	76.8326	38.7236
50.5	1.23478	1231.30	621.806	10.2756	5.18920	76.8676	38.8181
51.0	1.23756	1234.06	629.370	10.2987	5.25232	77.0399	39.2903
51.5	1.24034	1236.83	636.967	10.3218	5.31573	77.2128	39.7646
52.0	1.24313	1239.62	644.602	10.3451	5.37944	77.3869	40.2412
52.5	1.24593	1242.41	652.265	10.3684	5.44339	77.5611	40.7196
53.0	1.24874	1245.21	659.961	10.3917	5.50762	77.7359	41.2001
53.5	1.25156	1248.02	667.690	10.4152	5.57212	77.9113	41.6826
54.0	1.25439	1250.84	675.453	10.4387	5.63690	78.0874	42.1672
54.5	1.25723	1253.67	683.250	10.4623	5.70197	78.2641	42.6539
55.0	1.26007	1256.51	691.080	10.4860	5.76732	78.4414	43.1428

Table 1. (Continued)

°Brix or % by wt. sucrose	Apparent specific gravity 20/20°C	Wt./liter in air at 20°C (g)	Sucrose/liter in aid (g)	Wt./gal in air at 20°C (lb.)	Sucrose/gal in air (lb.)	Wt./ft³ in air at 20°C (lb.)	Sucrose/ft³ in air (lb.)
55.5	1.26293	1259.36	698.944	10.5098	5.83295	78.6193	43.6337
56.0	1.26580	1262.22	706.843	10.5337	5.89886	78.7978	44.1268
56.5	1.26868	1265.09	714.775	10.5576	5.96506	78.9770	44.6220
57.0	1.27156	1267.97	722.742	10.5817	6.03155	79.1568	45.1194
57.5	1.27446	1270.86	730.744	10.6058	6.09833	79.3372	45.6189
58.0	1.27736	1273.75	738.775	10.6299	6.16534	79.5176	46.1202
58.5	1.28028	1276.64	746.834	10.6540	6.23260	79.6981	46.6234
59.0	1.28320	1279.58	754.952	10.6786	6.30035	79.8816	47.1301
59.5	1.28614	1282.51	763.093	10.7030	6.36829	80.0645	47.6384
60.0	1.28908	1285.44	771.264	10.7275	6.43648	80.2474	48.1485
60.5	1.29203	1288.38	779. 470	10.7520	6.50496	80.4310	48.6607
61.0	1.29498	1291.33	787.711	10.7766	6.57373	80.6151	49.1752
61.5	1.29796	1294.30	795.994	10.8014	6.64286	80.8005	49.6923
62.0	1.30093	1297.26	804.301	10.8261	6.71218	80.9853	50.2109
62.5	1.30393	1300.25	812.656	10.8511	6.78191	81.1719	50.7325
63.0	1.30694	1303.25	821.047	10.8761	6.85194	81.3592	51.2563
63.5	1.30994	1306.26	829.475	10.9012	6.92227	81.5471	51.7824
64.0	1.31297	1309.27	837.933	10.9263	6.99286	81.7351	52.3105
64.5	1.31600	1312.29	846.427	10.9515	7.06374	81.9236	52.8407
64.8	1.31784	1314.12	851.549	10.9668	7.10649	82.0378	53.1605
64.9	1.31845	1314.73	853.260	10.9719	7.12076	82.0759	53.2673
65.0	1.31905	1315.33	854.964	10.9769	7.13499	82.1134	53.3737
65.1	1.31966	1315.94	856.677	10.9820	7.14928	82.1515	53.4806
65.2	1.32028	1316.55	858.390	10.9871	7.16358	82.1895	53.5876
66.0	1.32516	1321.42	872.137	11.0277	7.27830	82.4936.	54.4458

example, if one million gallons of single strength juice were desired at 11.8°Brix from 41.8°Brix concentrate, how much error in single strength °Brix would be incurred in 41.9°Brix concentrate were used?

Add 3 parts of water to 1 part of concentrate to make 1 million gallons of juice.

For 41.9°Brix concentrate,

$$\text{Total solids} = 4.14437 \times 250{,}000$$
$$= 1{,}036{,}093 \text{ lb.}$$
$$\text{pounds solids} = \frac{1{,}036{,}093}{1{,}000{,}000}$$
$$= 1.03609 \text{ lb./gal}$$
$$\text{°Brix} = 11.882 \text{ (calculated from Table 1).}$$

For 41.8°Brix concentrate,

$$\text{Total solids} = 1{,}033{,}165 \text{ lb.}$$
$$\text{pounds solids} = 1.03317 \text{ lb./gal}$$
$$\text{°Brix} = 11.850$$
$$\text{°Brix difference} = 11.882\text{-}11.850 = 0.032.$$

One tenth °Brix error at 41.8°Brix will result in 0.032°Brix in reconstituted single strength juice.

Technically 0.1°Brix is an acceptable tolerance for Brix measurement. It should be recognized that even such a small tolerance will mean a great deal of cost to the citrus industry. For example, Nielsen reported retail orange juice (OJ) sales in the United States were 484, 295, and 24.9 million gallons single strength equivalent for frozen concentrate, chilled, and canned, respectively, in the 1981-82 season (3). Using these figures, one tenth of one degree excess in Brix error in all products will translate into an estimated total seasonal solids cost of 5.3 million dollars at the assumed solids cost of $1.22 per pound for the citrus juice trade.

Accurate measurement of °Brix is one of several factors affecting the total product yield. Other important factors include juice extracting and container filling. For most other practical purposes, the use of 4- to 5-digit existing Brix-pounds solids tables will result in errors less than 0.1% which is much less than potential errors in °Brix measurement using the best available technique. In view of the importance of °Brix measurement, the most accurate and reliable instrument should be used to ensure the correctness of °Brix measurement in citrus processing plants. Accurate determinations of juice yield and °Brix are necessary to ensure fairness to growers and processors.

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