A great many other determinations were made on known samples and as stated above. Satisfactory results were always obtained in the case of lemon extracts, while the results on oils were not so good. The maximum error on oils was usually less than 0.5 per cent. while the average was in the majority of cases within 0.2 per cent.

The essential point to be observed in using the method is to keep the temperature of the reagents and the comparison tubes down to at least 15°, and give the standard and sample exactly the same treatment throughout.

[CONTRIBUTION FROM THE FOOD DIVISION OF THE BUREAU OF CHEMISTRY, U. S. DEPT. OF AGRICULTURE. SENT BY H. W. WILEY.]

ESTIMATION OF SUGARS BY MEANS OF THE REFRACTOMETER.

BY L. M. TOLMAN AND W. B. SMITH.

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IN A great many materials such as syrups, molasses, and similar substances which are for all practical purposes solutions of sugar and water, the estimation of sugar has long been made by determining the specific gravity with a hydrometer or pycnometer and from the specific gravity calculating the percentage of sugars from a table or by some formula.

This figure, if the solution is a mixture of a pure sugar and water, can be very accurately determined but in syrups and molasses which are impure mixtures, it represents more nearly a determination of the total substances in solution or the total solids. The determination of total solids is a very important one in a great many food products as a check on the other determination and it is for work of this kind that the specific gravity is of value. The accuracy of the specific gravity method in a mixed sugar solution such as we ordinarily have to deal with, depends on the fact that the different sugars have very nearly the same specific gravity for the same concentration. The specific gravity method is also especially useful with substances which are decomposed by drying at a high temperature, such as solutions containing large amounts of invert sugar, where results by drying are too low.

The index of refraction is a figure of practically the same value as the specific gravity in solutions of the kind mentioned above and has about the same limitations. The index of refraction of solutions of soluble carbohydrates increases regularly with the concentration, and the accuracy of the determination is limited only by the accuracy and sensitiveness of the refractometer. Stolle[1] published some results on the index of refraction of sugar solutions using the Pulfrich refractometer and showed that with sucrose, *d*-glucose, *δ*-*l*-fructose ("levulose") and lactose, there was little variation in the reading of the refractometer with solutions of the same concentration and that very accurate results could be obtained with pure sugar solutions. He also demonstrated that the relation between the index of refraction and specific gravity as calculated by the Lorenz formula $\frac{N_2-1}{(N_2+2)D}$ was a constant, 0.206, thus showing that the same results can be obtained by the index of refraction and the specific gravity.

The following work was undertaken to test the value and accuracy of the Abbé refractometer for this kind of work, to check up Stolle's work, and to complete the list of sugars, as he had no figures on maltose, commercial glucose, or the other soluble component of glucose, that is dextrin, which is often an ingredient of the commercial products on the market.

The instrument used was the new form of the Abbé refractometer with a water-jacket prism so that the temperature at which the readings were made could be exactly regulated. The index of refraction was obtained in exactly the same manner as when an oil is examined in the same instrument.

The instrument was standardized against a quartz plate with a known index of refraction and against pure water and found to read slightly low, about 0.0004, and the readings were corrected by this factor.

The readings were all made at 20°, using ordinary light and compensating for the dispersion by means of the prisms in the instrument. The sugar solutions were made up by weighing the sugars into a glass stoppered flask and then adding a weighed amount of water so that the results were direct percentages by weight.

[1] Z. Ver. deut. Zucker-Ind. 1901, 335–347 and 469–487.

The moisture in the various sugars was determined by drying at 70° to constant weight and at a diminished pressure of about 27 inches. It can be seen that a method of this kind would have many advantages in inspection work—the ease and rapidity with which a determination can be made and the ease and accuracy with which the temperature can be regulated as well as the small amount of sample needed for the determination give it many advantages over the specific gravity method.

The following curve shows graphically the results obtained with the various sugars.

The curve is drawn from the results obtained with sucrose up to a concentration of 65 per cent. from which point it was extended by calculation to 90 per cent. The points for commercial glucose between 80 and 90 per cent. were determined by readings with four different glucoses and they were found to coincide exactly with the calculated curve for sucrose; determinations with glucose of other concentrations, as shown on the curve, also coincide with the sucrose line.

The other sugars examined were maltose and lactose which are also on the sucrose curve, showing that for practical purposes all these sugars have the same index of refraction for the same concentration and that a table prepared for sucrose will be satisfactory for all.

The only other soluble carbohydrate examined was dextrin which, as is shown on the curve, has a slightly higher index of refraction. The close agreement between sucrose and commercial glucose, which is a mixture of dextrose, maltose, and dextrin, is due to the fact that dextrose and maltose have an index of refraction very slightly lower than sucrose while dextrin is slightly higher, the resultant being practically that of sucrose. The following table shows better than the curve, which is not on a sufficiently large scale, the difference between the various sugars.

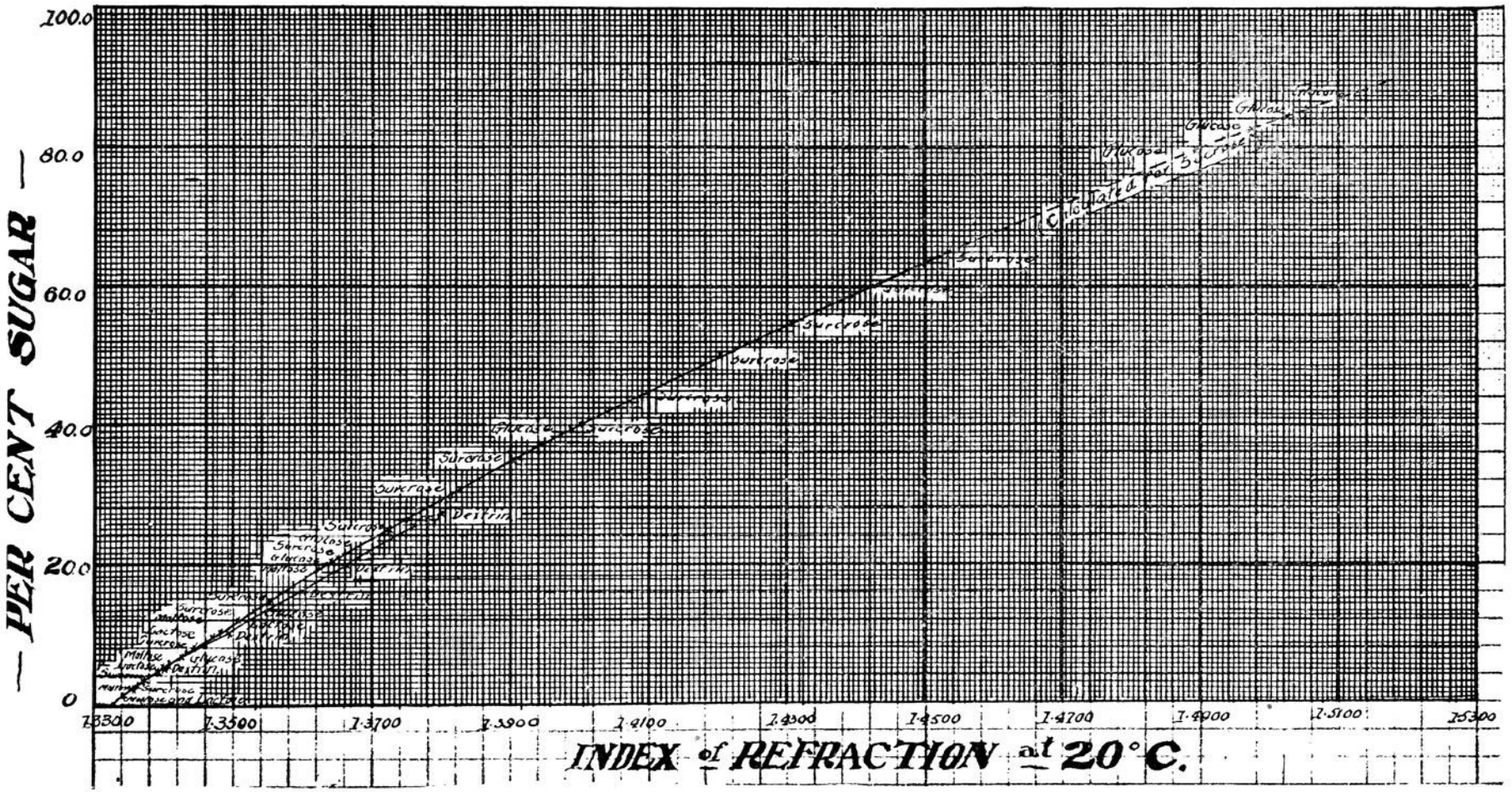
— PER CENT SUGAR —
100.0
80.0
60.0
40.0
20.0
0
1.3300
1.3500
1.3700
1.3900
1.4100
1.4300
1.4500
1.4700
1.4900
1.5100
1.5300
INDEX of REFRACTION at 20° C.
Sucrose
Dextrin
Maltose
Glucose
Fructose

TABLE I.—INDEX TO REFRACTION OF VARIOUS SUGARS OF DIFFERENT CONCENTRATION.

Dried in vacuum at 70° C. to constant weight.

Index of Refraction 20° C.	Sucrose. Per cent.	Maltose. Per cent.	Commercial glucose. Per cent.	Lactose. Per cent.	Dextrin. Per cent.	Stolle. *d*-Glucose. Per cent.	Stolle. *δ-l*-Fructose. Per cent.
1.3343	1.00	1.00	1.00	1.00	1.00	1.00	1.14
1.3357	2.00	2.07	2.00	2.00	1.93	1.80	2.07
1.3402	5.00	5.07	5.00	5.13	4.87	5.13	5.13
1.3477	10.00	10.07	10.07	10.13	9.60	10.13	10.13
1.3555	15.00	15.12	15.06	15.13	14.13	15.19	15.19
1.3637	20.00	20.17	20.06		18.94	20.29	20.24
1.3722	25.00		25.00		23.71	25.47	25.47
1.3810	30.00		30.02		28.78		
1.3902	35.00		35.03				
1.3997	40.00		40.05				
1.4096	45.00		45.04				
1.4200	50.00		50.03				
1.4306	55.00		55.02				
1.4419	60.00		60.01				
1.4534	65.00		65.01				
1.4653	70.00		70.00				
1.4776	75.00		75.00				
1.4903	80.00		80.00				
1.5034	85.00		85.00				
1.5170	90.00		90.00				

Taking sucrose as the standard, the other sugars in concentrations up to 20 per cent. show practically no difference in the reading on the refractometer. A reading of 1.3637 is equivalent to 20 per cent. of sucrose, 20.17 of maltose, 20.06 per cent. of commercial glucose, 20.29 per cent. of *d*-glucose, 20.24 per cent. of *δ-l*-fructose and 18.94 per cent. of dextrin. Dextrin alone of all the substances examined differs appreciably from sucrose, it having a slightly higher index of refraction.

The index of lactose is also very close to that of sucrose so that in most cases the same table can be used for all of the sugars in the same way that the Brix table is used for specific gravity determinations. The following table for the value of the index of refraction for sucrose for each per cent. up to 90 per cent. has been calculated from the curve, and for ordinary work this will be found satisfactory for all sugars.

TABLE II.—INDEX OF REFRACTION OF SUCROSE.

Sucrose. Per cent.	Index of refraction 20° C.	Sucrose. Per cent.	Index of refraction 20° C.	Sucrose. Per cent.	Index of refraction 20° C.
1	1.3343	31	1.3828	61	1.4442
2	1.3357	32	1.3847	62	1.4465
3	1.3372	33	1.3865	63	1.4488
4	1.3387	34	1.3883	64	1.4511
5	1.3402	35	1.3902	65	1.4534
6	1.3417	36	1.3921	66	1.4557
7	1.3432	37	1.3940	67	1.4581
8	1.3447	38	1.3959	68	1.4605
9	1.3462	39	1.3978	69	1.4629
10	1.3477	40	1.3997	70	1.4653
11	1.3492	41	1.4017	71	1.4677
12	1.3508	42	1.4036	72	1.4701
13	1.3524	43	1.4056	73	1.4726
14	1.3539	44	1.4076	74	1.4751
15	1.3555	45	1.4096	75	1.4776
16	1.3572	46	1.4117	76	1.4801
17	1.3588	47	1.4137	77	1.4826
18	1.3604	48	1.4158	78	1.4851
19	1.3621	49	1.4179	79	1.4877
20	1.3637	50	1.4200	80	1.4903
21	1.3654	51	1.4221	81	1.4929
22	1.3671	52	1.4242	82	1.4955
23	1.3688	53	1.4263	83	1.4981
24	1.3705	54	1.4284	84	1.5007
25	1.3722	55	1.4306	85	1.5034
26	1.3739	56	1.4328	86	1.5061
27	1.3756	57	1.4351	87	1.5088
28	1.3774	58	1.4373	88	1.5115
29	1.3792	59	1.4396	89	1.5142
30	1.3810	60	1.4419	90	1.5170

In order to correct for different reading temperatures, the following table was prepared, readings being made on the same solutions at 20°, and at 30°, and on concentrations varying from 2 per cent. to 62 per cent.

TABLE III —CORRECTION FOR TEMPERATURE.

Percentage of sugar.	Index at 20° C.	Index at 30° C.	Difference.	Correction for 10° in per cent. sugar.	Correction for 10° in per cent. sugar, from Brix table.
2.18	1.3358	1.3348	0.0010	0.66	0.64
7.43	1.3438	1.3428	0.0010	0.66	0.67
15.82	1.3569	1.3557	0.0012	0.70	0.70
51.71	1.4236	1.4219	0.0017	0.81	0.79
62.52	1.4477	1.4459	0.0018	0.78	0.76

The differences were calculated to per cent. of sugar and compared with the correction for temperature used in specific gravity work, the Brix table for correction for temperature being used. The results show that the temperature correction for the specific gravity and the index of refraction are practically the same and the table as given for Brix can be used for the index of refraction. The manner of using the table is the same. The reading of index of refraction is made at room temperature and this reading calculated to per cent. of sugar, then the proper correction from the table calculated and applied.

In the Brix table for correction for temperature the maximum correction is at a concentration of about 50 per cent. and, as will be seen from the table above, this same fact is noted in the temperature correction for index of refraction.

In conclusion: It appears from this work that the refractometer is a satisfactory instrument for determining the soluble carbohydrates in solution under the same conditions as those under which specific gravity can be used, and in fact it gives the same results; that it has many advantages over the specific gravity method in speed, ease of manipulation and amount of sample required for the determination; that for a great deal of work where quickness and approximate accuracy only are necessary, the refractometer will be used. The butyro-refractometer is of no value for this work as its range of readings does not take in sugar solutions below 50 per cent. of sugar.

THE OPTICAL ROTATION OF GLIADIN IN CERTAIN ORGANIC SOLVENTS.

By W. E. Mathewson.

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The experiments given here were carried out in connection with an investigation, the object of which was to effect some improvement on the present methods of flour analysis. The work has been interrupted so it has been thought best to publish these results.

The gliadin used was prepared from a bakers' grade hard wheat flour by extracting with 60 per cent. alcohol, filtering the extract until perfectly clear, concentrating and precipitating with absolute alcohol. The crude gliadin thus obtained was again dissolved and precipitated, digested repeatedly with ether and finally dried