DERE Application Note

°BRIX – Sugar Determination

By Density and Refractive Index

There exist many different types of sugars. Examples include sucrose, maltose, or glucose, but also mixtures like high-fructose corn syrup (HFCS). Strictly speaking, °Brix is defined as the number of grams of sucrose in 100 grams of a water-sucrose solution. In practice, however, the content of other sugars or sweeteners is often also expressed in °Brix. In these cases, the measured "°Brix" value is only an approximation of the actual sugar content. °Brix values are most easily measured via density or refractive index. For both methods, there exist tables to convert measured results into °Brix.

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What Is Brix?

1 °Brix is defined as 1 g of sucrose in 100 g of a water-sucrose solution. To prepare a 50 °Brix solution, 50 g of sucrose are weighed and water is added until the balance shows 100 g. Typical °Brix scales range from 0–85 °Brix. However, they can be extrapolated to 100 °Brix.

Two Methods to Measure °Brix

It is possible to measure °Brix either with a density meter or with a refractometer. Both methods give the same result if pure sucrose-water solutions are measured. Conventional measurement setups are shown in Figure 1. One example is the hydrometer which is used to determine °Brix via density. It has a relatively good resolution and is available at a moderate price. A big disadvantage of hydrometers is operator dependence of the measured results. Further, they are made of glass and are easily breakable.

Figure 1: Conventional setups to measure °Brix. From left to right: hydrometer, pycnometer, Abbe refractometer.

Another example is the pycnometer. It also allows °Brix measurements via density with a good accuracy. However, it is not suitable for daily quality control purposes, since one measurement takes up to 30 minutes.

Digital density meters and refractometers like the ones found in the METTLER TOLEDO Density Meter and METTLER TOLEDO Refractometer portfolio (Figure 2) allow easy, accurate and reliable measurements of °Brix. The variety of instruments ensures that METTLER TOLEDO can provide an optimal solution for every need met in the market. Both types of instruments allow the automatic conversion of the measured values into °Brix via built-in conversion tables.

Definition of Density

The density is the quotient of the mass *m* and the volume *V* of a substance. As the density depends strongly on the temperature, the latter should always be indicated. For example, the density of a substance at 20 °C is abbreviated with the symbol d^{20}.

$$d^{20} = \frac{m}{v^{20}} [kg/m^3] \; or \; [g/cm^3]$$

Table 1 shows an excerpt of a conversion table between density and °Brix at 20 °C. Conversion tables for further sugar-related scales stored on METTLER TOLEDO Excellence Density Meters are shown in Table 3.

Density meter		Accuracy	in °Brix	Refractometer		Accuracy	in °Brix
		g/cm³	% w/w			nD	% w/w
	Excellence line				Excellence line		
	D4	0.0001	0.03		R4	0.0001	0.05
	D5	0.00005	0.015		R5	0.00002	0.014
	D6	0.000005	0.002				
	EasyPlus line				EasyPlus line		
	EasyD30	0.001	0.2		EasyR40	0.0001	0.05
	EasyD40	0.0005	0.1		EasyBrix	0.0001	0.05
					Easy Bev	0.0001	0.05
	Handheld line				Handheld line		
	Densito	0.001	0.3		Refractometer 30GS/PX	0.0005	0.2
					MyBrix	0.0003	0.2

Figure 2: Modern setups to measure °Brix. Three METTLER TOLEDO digital density meters (left) and four METTLER TOLEDO digital refractometers (right).

°Brix	d^{20}
5.0	1.017821
6.0	1.021824
7.0	1.025856
8.0	1.029909
9.0	1.034002
10.0	1.038114
11.0	1.042257
12.0	1.046429
13.0	1.050632
14.0	1.054874
15.0	1.059136
16.0	1.063429
17.0	1.067761
18.0	1.072113
19.0	1.076505
20.0	1.080927
21.0	1.085379
22.0	1.089871
23.0	1.094393
24.0	1.098945

Table 1: Excerpt of NBS 113 conversion table between density and °Brix. The full table ranges from 0-83 °Brix.

Definition of Refractive Index

The refractive index of a medium *n* is defined as the quotient of the speed of light *c* in vacuum and the speed of light in a medium *v*.

$$n = c/v$$

It also indicates the ability of a medium to bend, or refract, light. If a light beam crosses the interface of two media with refractive indices n_1 and n_2, refraction is described by Snell's law of refraction

$$n_1 * \sin(\Theta_1) = n_2 * \sin(\Theta_2)$$

where Θ_1 and Θ_2 depict the angles of incidence and refraction, respectively.

The refractive index depends on the wavelength of the incident light. The standard wavelength for refractive index determinations is the sodium D-line at 589.3 nm. This is also the wavelength at which METTLER TOLEDO instruments operate. The respective refractive index is abbreviated as n_D.

The refractive index is also dependent on the temperature of the medium, requiring temperature control for exact measurements. The refractive index of a substance at 20 °C is abbreviated with the symbol n_D^{20}.

As with density, °Brix values are calculated from refractive indices via conversion tables (Table 2). Conversion tables for other sugar scales stored on METTLER TOLEDO Excellence Refractometers are shown in Table 3.

°Brix	n_D^{20}
0	1.33299
5	1.34026
10	1.34782
15	1.35568
20	1.36384
25	1.37233
30	1.38115
35	1.39032
40	1.39986
45	1.40987
50	1.42009
55	1.43080
60	1.44193
65	1.45348
70	1.46546
75	1.47787
80	1.49071
85	1.50398
90	1.51768
95	1.53178
100	1.54629

Table 2: Selected values of OIML R 124 refractive index conversion table. The full table shows all °Brix values in steps of 1°. The same table is used by ICUMSA™.

Scale	Description	d	n_D
Brix NBS 113	Sucrose content (% w/w), NBS table 113	x	
Brix Emmerich	Sucrose content (% w/w), A. Emmerich, Zuckerindustrie 119 (1994)	x	
Brix @Tx	Sucrose content (% w/w) at measured temperature without temperature compensation, OIML R 108 (1993)		x
Brix comp 20 °C	Sucrose content (% w/w) temperature compensated to 20 °C, ICUMSA™[1]		x
Plato	Beer extract sugar content (% w/w), from density at 20 °C	x	
HFCS42	Content of HFCS syrup with 42% fructose fraction at 20 °C	x	x
HFCS55	Content of HFCS syrup with 55% fructose fraction at 20 °C	x	x
Invert sugar	Invert sugar content at 20 °C	x	x
Oechsle	Measure of sugar content and ripeness in grapes	x	x
KMW	Klosterneuburg Mostwaage scale. Sugar content in grape juice at 20 °C (Austria)	x	
Babo (KMW)	Sugar content in grape juice at 20 °C (Italy)	x	
Further sugars	D-Fructose, D-Glucose, D-Mannitol, Dextran, Lactose, Maltose	x	

Table 3: Commonly used conversion tables based on refractive index (nD) or density (d).

[1] ICUMSA™ is a trademark of ICUMSA Ltd. and Verlag Dr. Albert Bartens KG.

Where Is °Brix Measured?

Although the designation "°Brix" is strictly valid only for pure sucrose-water solutions, in practice, the term as well as the methods of measurement described here are often used loosely for any sugar-like component in a sample. Consequently, many samples containing sugars or sweeteners can be subjected to °Brix determination. Typical examples include soft drinks, sauces, juices, honey, and grape must in wine production. Note, that °Brix values for samples that are not mere sucrose-water solutions are only approximations of the real sugar content. Further, using °Brix conversion tables for sugars other than sucrose, also only yield approximations. If available, conversion tables for the specific sugar of interest should be used.

Since measured °Brix values for such samples are not "true" °Brix values, results obtained from density and refractive index measurements are not identical (Table 4).

°Brix measurements are not only important for quality control in the food and beverage industry but also for formulation of consumables with the correct amount of sugar. Some products like sugar syrups intended for beverage production are sold by weight and sugar content. The determination of °Brix is therefore crucial for price determination.

Sample	Density °Brix	Refrac. °Brix	Comment
20% sucrose solution	20.00%	20.00%	Identical because pure water-sucrose solution.
Orange juice	11.38%	11.54%	Different because not pure water-sucrose solution. Especially acidity has an influence on values obtained by different measuring techniques.
Molasses	43.92%	42.20%	Residue from sugar production. Different, since only about 50% of sugars in molasses is sucrose.
20% glucose solution	39.26%	39.44%	Different because not sucrose.
40% fructose solution	41.06%	39.35%	Different because not sucrose.

Table 4: Comparison of °Brix values obtained from density and refractive index. Note, that for glucose and fructose separate conversion tables exist that would yield the correct results.

Temperature and Concentration Effects

°Brix determinations are affected by temperature, requiring temperature correction for measurements at temperatures different than 20 °C. In addition, the temperature correction coefficients for °Brix measurements are concentration dependent.

The °Brix values at various concentrations obtained from refractive indices can be temperature-corrected according to ICUMSA (Table 5). For example, if a 60 °Brix solution is measured at 25 °C, 0.40 °Brix need to be added to the measured value to get the compensated value for 20 °C.

Temp. / °C	20 °Brix	40 °Brix	60 °Brix	80 °Brix
	To be subtracted from the mass fraction			
15	0.34	0.37	0.38	0.37
…	…	…	…	..
	Effective n_D value at 20 °C			
20	1.363842	1.399860	1.441928	1.490708
	To be added from the mass fraction			
…	...	…	…	…
25	0.38	0.40	0.40	0.38
…	…	…	…	…
40	1.73	1.72	1.66	1.54

Table 5: Selected correction factors for °Brix values at various temperatures according to ICUMSA. Due to copyright reasons, the full table is not shown here.

Figure 3 shows the temperature dependence of the °Brix value as obtained by refractive index for two water-sucrose solutions with varying sugar content. One solution contains 10 °Brix, the other one 65 °Brix.

While METTLER TOLEDO benchtop density meters and refractometers are able to closely regulate the measurement temperature, the handheld instruments rely on built-in temperature compensation. Note, that, strictly speaking, the °Brix temperature compensation scheme is only valid for pure sucrose-water solutions.

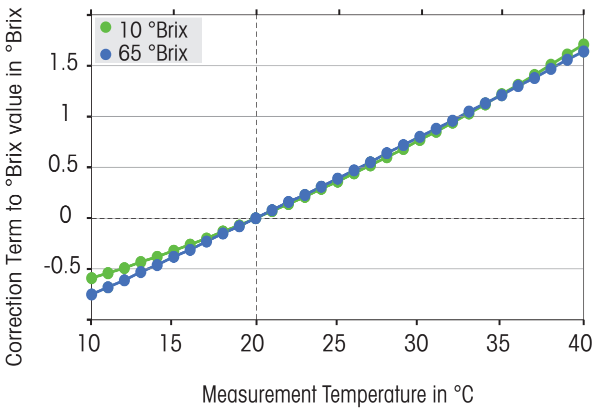

Figure 3: Temperature dependency of °Brix values of water-sucrose solutions with 10 °Brix and 65 °Brix as obtained by refractive index.

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Conclusions

Modern digital density meters and refractometers present a fast and reliable way of measuring °Brix, or other parameters used to determine the content of sugar or sugar-related compounds. Both measuring techniques produce highly reproducible and mostly operator-independent results. In contrast to conventional manual measurements, METTLER TOLEDO Digital Density Meters and Refractometers do not require highly trained personal to achieve accurate and repeatable results. A built-in Peltier thermostat in the EasyPlus™ and Excellence™ line instruments allows accurate measurements at various temperatures. Automatic temperature compensation ensures conversion of results to 20 °C or any other desired temperature in handheld devices.

In addition, Excellence line instruments can be connected to various automation options and even be integrated into multiparameter systems, in case multiple analytical methods are required for one sample. Data management and connection of all Excellence line instruments in compliance with international data management standards is made possible with the powerful METTLER TOLEDO laboratory software LabX™.

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