BRIX - Sugar Determination

By Density and Refractometry

Introduction
There are a lot of different sugars, e.g. sucrose, malt sugar, glucose, HFCS. Strictly speaking of Brix,only the pure sucrose content in a solution is meant. But often as well, the High Fructose Corn Syrup (HFCS) is measured and expressed in Brix °. This sugar concentration can be measured with density meters and refractometers. Both instruments are capable to convert the measured experimental data automatically into Brix degrees or HFCS.

What is Brix ?
Brix is the measurement in percentage by weight of sucrose in pure water solution. This designation of Brix degrees is only valid for pure sucrose solutions. Pure sucrose is extracted from sugar-cane or sugar-beet.

What is HFCS ?
High Fructose Corn Syrup (HFCS) is a liquid sweetener that is extracted from cornstarch containing mainly Fructose and D-Glucose. HFCS is used to replace sucrose in the beverage and food industries. HFCS is available in three different fructose levels HFCS 42%, 55% and 90% weight percent and is mainly used in the USA.

Two methods to measure Brix and HFCS
It is possible to measure the Brix and HFCS content either with a density meter or a refractometer. Both methods will give the same result if pure sucrose/HFCS content of a solution is measured.

Old methods to measure Brix

Brix Hydrometer, Pycnometer, Abbe Refractometer

New methods to measure Brix

Digital Density Meters   Digital Refractometers

Brix Hydrometers are widely used for measurement of Brix. They have a relatively good resolution of ± 0.05 on syrup and ±0.02 Brix on beverage, and are available at reasonable prices. One disadvantage of Hydrometers is that due to different operators and the way of working (e.g. put down the hydrometer calmly) the results may differ a lot. The Hydrometers are made of glass and therefore highly breakable.

Pycnometers allow measurement with a good accuracy, but are not suitable for daily control since it takes about 30 minutes for each measurement.

Digital Density Meters and Refractometers like the DM40 Density Meter and the RM40 Refractometer from Mettler-Toledo allow to measure directly Brix degrees or HFCS %. Both measuring methods allow the automatic conversion of refractive index / density into Brix degrees or HFCS %. With both methods the obtained results are identical when measuring pure sucrose or pure HFCS and can be compared with each other.

The following tables show the conversion between refractive index resp. density to Brix at 20°C.

Refractive Index (1)

Brix %	nD_{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

(1) According to 16th Session of ICUMSA 1974

Density (2)

Brix %	SG_{20}
0	1.00000
5	1.00965
10	1.03998
15	1.06104
20	1.08287
25	1.10551
30	1.11898
35	1.15331
40	1.17853
45	1.20467
50	1.23174
55	1.25976
60	1.28873
65	1.31866
70	1.34956
75	1.38141
80	1.41421
85	1.44794
90	1.48259
95	1.51814

(2) Specific gravity according to 109 of NBS Circular 440

Definition of Density

The density is the quotient of the mass m and the volume V of a substance (mass density). As the density depends primarily on the temperature, the latter must always be specified.

$$d = m/V \ [kg/m^3] \text{ or } [g/cm^3]$$

More information can be found at: www.density.com

There is a direct relationship between density and BRIX. The measured density can be converted directly into weight percent sucrose content (°Brix). This conversion is based on table 109 of NBS Circular 440. Other conversion tables are also available, which are stored in the DM density meters:

Commonly used tables based on density

Plato	Extract-content in percentage weight (% w/w), Plato table, from true density at 20°C
Brix NBS 113	Saccharose content in percentage weight (% w/w), NBS table 113, from true density at 20°C
Brix Emmerich	Saccharose content in percentage weight (% w/w), according to A. Emmerich, Zuckerindustrie 119 (1994), from true density at 20°C
HFCS42	%-weight HFCS syrup (High Fructose Corn Syrup) with 42 % fructose fraction, based on true density at 20°C. Must be measured at 20°C.
HFCS55	%-weight HFCS syrup (High Fructose Corn Syrup) with 55 % fructose fraction, based on true density at 20°C. Must be measured at 20°C.
Invert sugar	%-weight invert sugar, based on true density at 20°C. Must be measured at 20°C.
KMW	Klosterneuburg sugar grade (Austria). Precise sugar content in grape juice. Based on true density at 20°C.
Babo (KMW)	Sugar content in grape juice (Italy). Based on true density at 20°C.
Oechsle	Oechsle degree in grape juice, based on the specific weight at 15°C. °Oe = (SG-1) * 1000, with d in g/cm3

Definition of Refractive Index

If a ray of light travels from one medium into another optically less dense one, it changes direction. With increasing angle of incidence, it reaches a critical value at which no light escapes from the denser medium. If this critical angles is exceeded, total reflection occurs. The refractive index is calculated from this critical angle. As the refraction depends on the wavelength of the incident light, the refractive index is measured at the wavelength of the D line of sodium (589.3 nm) as standard and symbolized by nD. The refractive index depends not only on the wavelength used to measure, but also on the temperature of the solution being measured.

More information can be found at: www.refractometry.com

There is a direct relationship between the refractive index and BRIX. The measured refractive index is converted directly into weight percent sucrose content (°Brix). This conversion is based on ICUMSA (International Commission for Uniform Methods of Sugar Analysis).

Where is Brix and HFCS measured and why

For any sample containing sucrose or HFCS the measurement of Brix can be done to obtain the solid component of sugar. Brix is defined as percent-weight containing in pure sucrose solution. For sugars other than sucrose, it is called the "apparent Brix" and is always a relative value. Although the designation of Brix is strictly valid only for solutions whose solids are entirely sucrose, the industry uses the measurement somewhat loosely as a reference value to measure any sweet solids in a product.

Any other sugar product as sucrose can therefore not give the correct Brix value. When determining the Brix degrees on e.g.

- malt sugar
- glucose
- honey

the obtained results are not the true Brix degree and are only relative values. Obtained Brix values on a non sucrose measurement with Density meter or Refractometer can therefore not be compared.

The following table shows BRIX measurement results on different samples measured once with a density meter and once with a refractometer. The two results are only identical if pure sucrose solutions are measured; on all other measurements the results show different values with the two test methods.

Sample	**Density Brix**	**Refrac. Brix**	**Comment**
20 % Sucrose solution	20.00%	20.00%	Identical because only sucrose
Orange juice	11.38%	11.54%	Different because of relative BRIX measurement. Especially acidity has an influence on different measuring techniques.
Molasses	43.92%	42.20%	Residue from sugar production only about 50% of molasses is sucrose. Different because only relative BRIX measurement.
Maltose	20.02%	20.34%	Different because of relative BRIX measurement.
Fructose	39.95%	40.01%	Different because of relative BRIX measurement.

Brix measurements are mostly done in the food industry for quality control reasons e.g. sucrose solution (sugar syrup). Sugar syrup intended for beverage and similar products is sold by weight and sugar content. The exact determination of Brix is therefore very important for cost and quality control in the beverage industry (soft drinks). For the finished product in the beverage industry the HFCS content is important for the quality control as one of determined quality value.

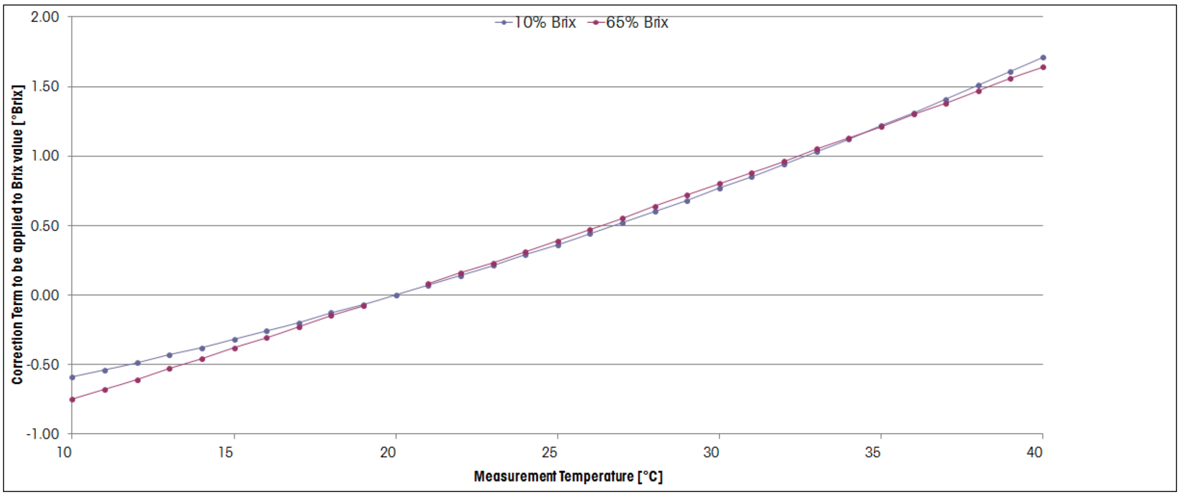
Temperature and Concentration Effects

The Brix and HFCS content measurement is influenced by temperature. The temperature correction coefficient is concentration dependent if measuring BRIX or HFCS concentration.
For refractometers the Brix value can be corrected according to the R124 table from OIML.

Temp. ˚C	Brix % 20	Brix % 40	Brix % 60	Brix % 80
to be subtracted from the mass fraction				
15	0.34	0.37	0.38	0.37
19	0.07	0.08	0.08	0.08
Effective nD value at 20 ∞C				
20	1.36384	1.39986	1.44193	1.49071
to be added from the mass fraction				
21	0.07	0.08	0.08	0.08
25	0.38	0.40	0.04	0.38
30	0.79	0.81	0.81	0.77

Temperature correction of the refractive index with different concentration of a sucrose solution

The graph below shows the temperature dependency of 10% and 65% sugar solutions



The temperature correction is concentration dependent and therefore it is recommended to measure at the desired temperature, if possible. Handheld digital density meters and refractometers have built-in temperature compensations for Brix and HFCS measurements. Note: These compensations are only valid for pure sucrose or HFCS. In addition, modern benchtop density meter and refractometers allow to enter product specific temperature compensation tables.

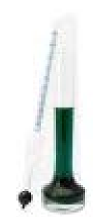
Commonly used tables based on refractive index

Brix @ Tx	Saccharose content in %.weight as per ICUMSA, 20th session in Colorado Springs (1990). Also corresponds to OIML R 108 (1993). Result without temperature compensation to 20°C.
Brix comp 20C	Saccharose content in %.weight as per ICUMSA, 20th session in Colorado Springs, 1990. Also corresponds to OIML R 108 (1993). Result compensated to 20°C.
Invert sugar	% weight invert sugar, as per ICUMSA, 20th session in Colorado Springs (1990). Result without temperature compensation to 20°C.
HFCS 42	% weight HFCS syrup (High Fructose Corn Syrup) with 42 % fructose fraction. Based on the refractive index at 20°C. Must be measured at 20°C.
HFCS 55	% weight HFCS syrup (High Fructose Corn Syrup) with 55 % fructose fraction. Based on the refractive index at 20°C. Must be measured at 20°C.
Oechsle	Oechsle degree from grape juice, based on the refractive index at 20°C.

Comparison of old and new methods for density measurement and benefits

Density

Old Method


Hydrometer


Pycnometer

New Method


Digital Density Meters

Step 1: Adjustment

Hydrometer	Pycnometer	Digital Density Meter
Certified adjustment necessary	No adjustment needed due to testing method	With air and water, air and Brix standard or 2 known standards

Benefits of digital density meters:

- Fully automatic with air and water
- Quick and easy
- Tracable adjustment according to GLP (print-out of adjustment data)

Step 2: Sample preparation

Hydrometer	Pycnometer	Digital Density Meter
Fill sample into beaker	Fill sample into pycnometer	Inject sample with syringe or use automation

Benefits of digital density meters:

- Quick and easy, especially compared to Pycnometer.
- No readjustment of volume caused by temperature change
- Small sample volume.
- Handling of sticky and high viscous samples is reduced to a minimum.

Step 3: Temperature control

Hydrometer	Pycnometer	Digital Density Meter
External thermostatic unit	External thermostatic unit	Built-in thermostat

Benefits of digital density meters:

- Rapid and very accurate, due to small sample volume
- No thermostatic unit required
- No moisture condensing, water sensitive products
- Elimination of temperature control errors
- Measurement temperature always at desired temperature, no temperature correction needed

Step 4: Measurement

Hydrometer	Pycnometer	Digital Density Meter
Buoyancy (read floating level)	Weighing (weigh pycnometer of known volume filled with sample)	Oscillation (measures oscillation frequency of U-tube filled with sample)

Benefits of digital density meters:

- Starts on a keystroke, and then fully automatic
- High reproducibility (not dependent on operator's accuracy)
- Rapid, easy and highly accurate
- Waits until stabilization of temperature and measuring value
- No visual reading errors
- Series measurements very quick, if desired fully automatic with sample changer
- Full Brix range
- Sample changers can be used to measure sample series

Step 5: Results

Hydrometer	Pycnometer	Digital Density Meter
Manual computing	Manual computing	Print-out of BRIX Data transfer to computer or LIMS

Benefits of digital density meters:

- Direct conversion and print-out of BRIX (no manual error prone, no look up in tables)
- High accuracy (up ± 0.006% BRIX)
- Print-out according to GLP
- Can be transferred to a computer/LIMS
- The results are not affected by individual operator techniques

General Benefits of Digital Density Meters

- Measurements are very quick and accurate
- Easy to operate
- Reducing of errors, possibility to be operated by unskilled people
- No breakable glassware
- Direct calculation of BRIX
- Less sample, less waste
- Easy to clean
- Sample changer for automatic series measurements
- Data transfer to computer or LIMS

Comparison of old and new methods for refractometry measurement and benefits

Refractometry	
Old Method	New Method
	
Abbe Refractometer	Digital Refractometer

Step 1: Adjustment

Visual Abbe Refractometer	**Digital Refractometer**
With certified glass	With water or Brix standard

Benefits of digital refractometers:

- Automatic, quick and easy adjustment with water or known standards
- No breakable glass to calibrate as with Abbe (very expensive due to high precision of glassware)

Step 2: Sample preparation

Visual Abbe Refractometer	**Digital Refractometer**
Add sample to prism	Add sample to prism

Benefits of digital refractometers:

- Easy, because only adding to prism no closing of measuring prism. This closing can lead to errors if sample is squeezed out of the measuring gap. New filling is then necessary

Step 3: Temperature control

Visual Abbe Refractometer	**Digital Refractometer**
External thermostatic unit	Built-in electronically controlled thermostat (Peltier)

Benefits of digital refractometers:

- Very accurate and fully automatic temperature control (no stepwise readjustment of thermostatic bath required)
- Short waiting time for temperature equilibrium
- No temperature compensation need, measurement at desired temperature, eg. 40°C or 60°C.
- No breakable glass to calibrate as with Abbe (very expensive due to high precision of glassware)

Step 4: Measurement

Visual Abbe Refractometer	**Digital Refractometer**
Manual reading of measurement	Digital reading measurement

Benefits of digital refractometers:

- Rapid, easy and highly accurate
- Fully automatic start of measurement at desired temperature and results equilibrium (absence of operator)
- Automatic BRIX measurement
- No errors, due to of human-eye reading
- Series measurements very quick, if desired fully automatic with sample changer
- Sample changers can be used to measure sample series

Step 5: Results

Visual Abbe Refractometer	**Digital Refractometer**
manual computing	Print-out of BRIX Data transfer to computer or LIMS

Benefits of digital refractometers:

- Results are not affected by individual operator techniques
- Direct conversion and print-out of BRIX (no manual error prone, no look up in tables)
- Print-out according to GLP
- Data transfer to computer or LIMS
- Sample changer for automatic series measurements

Conclusion

Modern digital density meters and refractometers offer a flexible way of either measuring the BRIX and HFCS concentrations, as well as other units used to measure sugar related content. Both methods will give rapid and highly reproducible results. The results are operator independent. No need for an external thermostatic bath, the built-in Peltier thermostat allows quick and highly accurate measurements. These digital instruments can be connected to a sample changer for measurement of sample series and to a computer or LIMS for data transfer. Thanks to all this features the instruments can be placed in the quality control laboratory for quick, easy and highly accurate measurements. The LiquiPhysics density meters and refractometers have a built-in Quality Control feature which compares the measured value for a product with the lower and upper limits defined for this product and give an immediate pass/fail result.

More information can be found at:
www.density.com www.refractometry.com