# Sugar Inversion and Brix in Soft Drinks: Cobrix3 multibev Measures Both!

## 1. Introduction

Soft drinks are produced from syrup (or concentrate), water and carbon dioxide. An important quality control parameter during production is the density of the syrup and the finished product, mainly reflecting the concentration of sweetener. For further details, see the Anton Paar's process application note "On-line Density Measurement in the Soft Drink Industry" [1].

**„Sugar"** (= saccharose = sucrose) is the traditional sweetener used for the production of soft drinks and is derived from cane or beets. Its concentration is given in °Brix (= %w/w).

Soft drink producers who use sucrose as the sweetener face the problem of "**sugar inversion":**

During storage, sucrose solutions undergo a slow conversion into a 1:1 mixture of glucose and fructose, also called **„invert sugar".** Each molecule of sucrose splits into one molecule of glucose and one molecule of fructose (see fig. 1) at the same time consuming one molecule of water. This "sugar inversion" is enhanced by the presence of acids (contained in most beverages) and by elevated temperatures.

Due to the inversion process, the density of the sugar solution increases causing a considerable change in the °Brix value e.g. from 10.40 °Brix (**Brix-fresh**) to 11.98 °Brix (**Brix-inverted**). Depending on inversion degree the Brix value (**Brix-actual**) will lie between **Brix-fresh** value and **Brix-inverted** value.

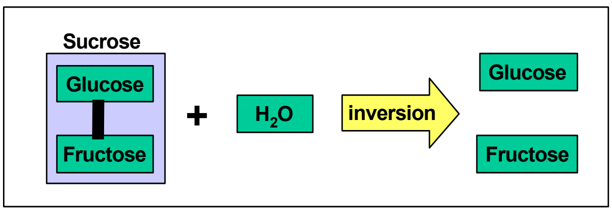


*Fig. 1 The „sugar inversion" process*

The recipe for the production of a specific soft drink is either based on the sucrose concentration in the fresh product or total inverted product. Since the density of a sugar solution increases during storage, density measurement does not give precise information about the "real" initial sucrose content.

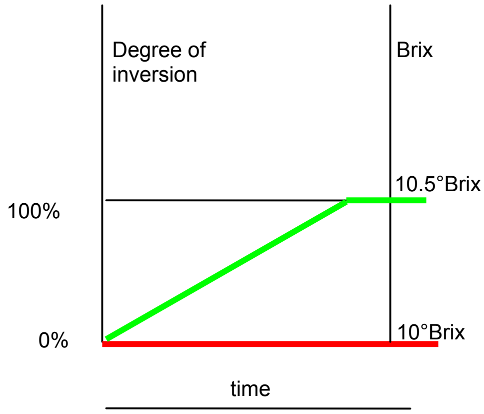


*Fig. 2 Degree of inversion over time*

Constant product quality of a soft drink greatly depends on the correct mixing ratio of the syrup with water. This mixing ratio can only be determined if the original sucrose concentration (°Brix-fresh) or the glucose- und fructose concentration at complete inversion (Brix-Inverted) of the syrup is known. The determination of **°Brix-fresh** from partially or completely inverted syrups is therefore very important.

For QC purposes the °Brix-fresh or the Brix-inverted of finished products must also be determined. Since the density changes during storage depending on the degree of inversion, °Brix-fresh or Brix-inverted is the only meaningful result which can be used to compare different production batches.

## 2. Determination of Brix-fresh and Brix-inverted

There are 2 ways to determine the °Brix-fresh and Brix-inverted of an inverted sucrose solution:

(1) The traditional "Forced Inversion Method": All the sucrose is forced to invert fully by adding acid and increasing the temperature. The final solution contains invert sugar (1:1 mixture of fructose and glucose). By measuring the density using the corresponding tables it is possible to determine the invert sugar concentration and calculate the original sucrose content (= °Brix-fresh).

(2) The more convenient "Anton Paar Method": The density and sound velocity of the partially inverted sample are measured and °Brix-fresh or Brix-inverted is automatically calculated using a special software. The principle of the calculation is described below [2].

Figure 3 shows the dependence of density and sound velocity on pure sucrose and invert sugar concentrations with increasing concentration.

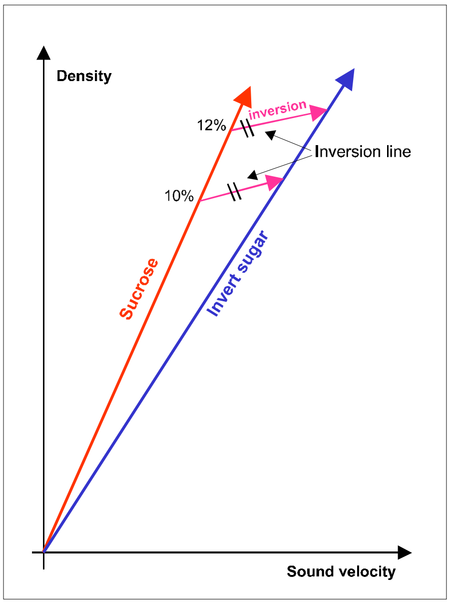


*Fig. 3 Density and sound velocity dependent on sucrose and invert sugar concentrations*

Partially inverted sucrose solutions contain both, invert sugar and sucrose. The density and sound velocity measuring points are therefore located between the two lines.

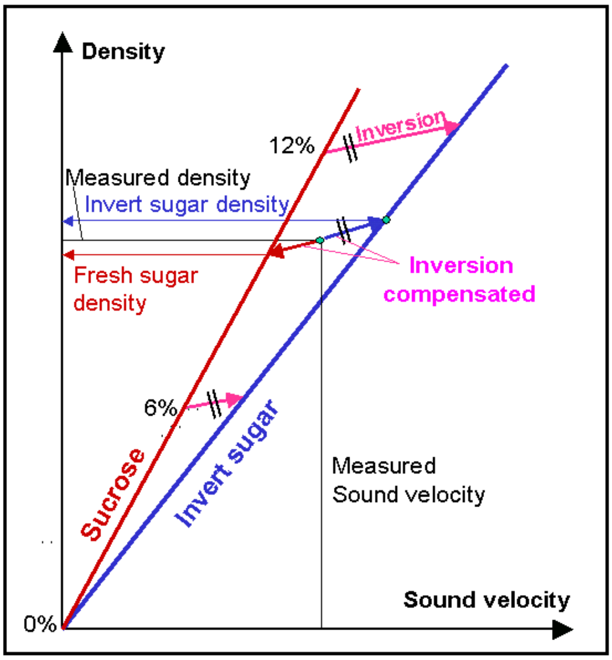


*Fig. 4 Determining the inversion compensated density*

To calculate the density of the initial sucrose solution, a line parallel to the inversion line has to be drawn through this measuring point. The crossing point of this line with the sucrose line gives the density of the initial sucrose solution. The crossing point of this line with the inverted sugar line gives the density of completely inverted solution (see fig. 4.).

The quality control of inverted sugar solutions in the laboratory is carried out using the **DSA 5000 Soft Drink Analyzer** from Anton Paar. The inversion compensation of the measured density and the calculation of °Brix-fresh are performed automatically (see figure 3).
For further information, see Anton Paar's application note „Sugar Inversion and °Brix in Soft Drinks: DSA 5000 Measures Both!" [3].

For the on-line quality control of inverted soft drinks the **Cobrix3 multibev beverage analyzer for sugar inversion** is used.

The Cobrix3 multibev measures density, sound velocity, temperature and $CO_2$ content simultaneously.
The measured density is compensated for temperature and $CO_2$ (measured with the integrated CARBO 2100 $CO_2$ transducer). The density reading is also compensated for sugar inversion using the sound velocity reading (see fig.5).

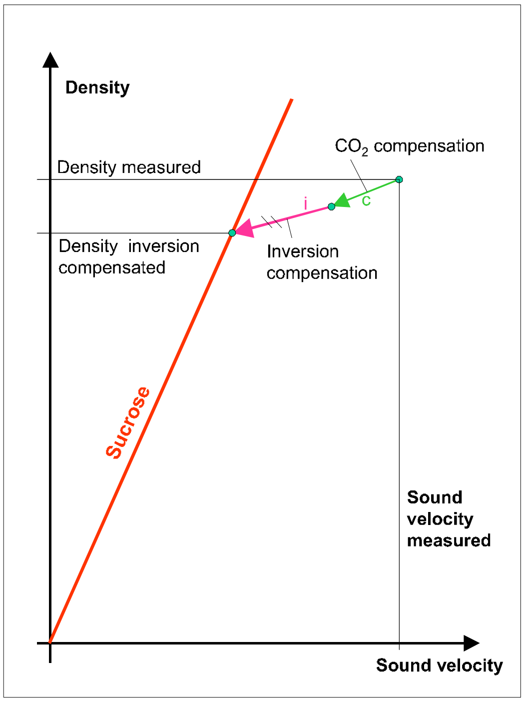


*Fig. 5 Determining the inversion and $CO_2$ compensated density*

## 3. On-line measuring principles

### 3.1 Density and sound velocity measurement

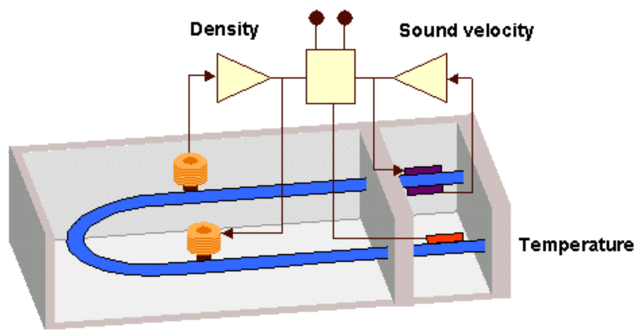


*Fig. 6 Diagram of a DSRn transducer*

In the Anton Paar DSRn transducer, density is measured according to the oscillating U-tube technique.
The U-shaped sample tube is made of Hastelloy C276 and is excited to a continuous oscillation at its natural frequency by means of a magneto-electrical excitation system. The oscillation frequency is related to the density of the sample flowing through the tube. Sound velocity is measured by an ultrasonic transmitter and receiver located on one side of the U-tube. The electronics measures the propagation time of the ultrasonic pulses through the sample and calculates the sound velocity. Information on the oscillation period, sound velocity and temperature is transferred to the evaluation unit and used for the calculation of concentrations.

When measuring carbonated soft drinks, the influence of carbon dioxide has to be considered as well. $CO_2$ measurement is performed with the CARBO 2100 $CO_2$ transducer.

### 3.2 Carbon dioxide measurement

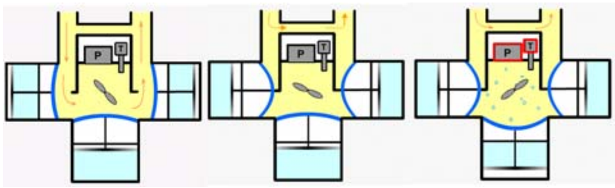

*Fig. 7 Measuring principle of the CARBO 2100*

The method for determining the $CO_2$ content is based on Henry's Law, which defines the relationship between the concentration of the dissolved gas and its saturation pressure.

A sample of the product is separated in a small measuring chamber. A special Anton Paar degassing device brings the chamber pressure to the corresponding saturation pressure within a few seconds. Then the saturation pressure and the temperature of the sample are measured and the content of dissolved $CO_2$ is calculated and used for density compensation.

The measurement is repeated every 15 seconds.

The conversion of saturation pressure and temperature into a $CO_2$ content is based on the formulas by Prof. Dr. Manfred H. Pahl, Dipl. Ing. Markus Rammert, University Paderborn [4].

## 4. The Cobrix3 multibev for sugar inversion

| **Cobrix3** | **multibev for sugar inversion** |
|---|---|
| consists of | • density sensor for °Brix and %Diet analysis<br>• sound velocity sensor for<br>- automatic compensation of sugar inversion<br>- determination of alcohol content<br>• $CO_2$ Transducer for carbon dioxide determination<br>• data processing unit<br>• pump with new liquid sensor and pump control<br>• flow monitor<br>• process-matched IP 55 (NEMA) housing and frame<br>• DAVIS data acquisition and control software for Windows™ |
| measures | density,<br>sound velocity,<br>carbon dioxide ($CO_2$),<br>temperature |
| performs | automatic inversion, temperature and $CO_2$ correction of density |
| determines | • °Brix-fresh<br>• °Brix-inverted<br>• °Brix-actual<br>• % Diet<br>• % Alcohol<br>• Density<br>• Extract<br>• Original extract<br>• Actual extract<br>• apparent extract<br>• Fermentation degree<br>• CO2<br>• Line pressure<br>• Temperature<br>• NaOH concentration<br>• etc. |

- The Cobrix3 multibev is a compact system with all its components (DSRn, CARBO 2100, mPDS 2000V3, valves, pump,…) mounted onto a rack. Within one day the system is installed and ready to go.
- The compact design of the Cobrix3 multibev guarantees optimal measuring conditions (constant flow rate,…).

- The Cobrix3 multibev provides real-time data of the measured parameters, activates alarms if pre-selected concentration limits are exceeded and provides signals for controller or recording devices.
- The Windows™ based DAVIS software is easy to use and performs data acquisition and statistical analysis for different products.
  Measuring data are displayed in diagrams that facilitate the monitoring of the production process.

For practical information on the Cobrix3 multibev with sugar inversion compensation, see the report „QC in real-time“ in Beverage World International, Nov/Dec 1998.

## 5. Applications and benefits

### 5.1. Installation of Cobrix3 multibev at the Filler

The on-line quality control of inverted soft drinks at the filler can be carried out using the **Cobrix3 multibev beverage analyzer for sugar inversion.** °Brix-fresh, °Brix-inverted, °Brix-actual and the $CO_2$ content are continuously monitored to assure constant product quality.

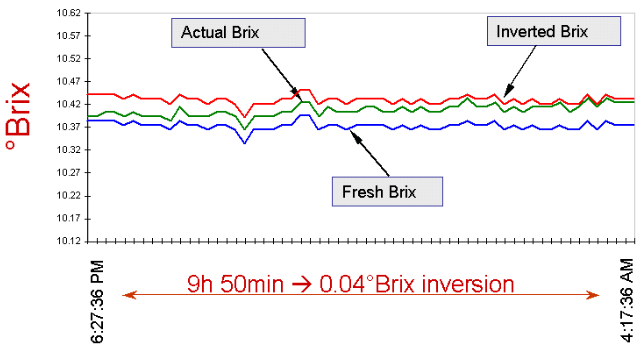


*Fig.8 Inversion over time*

**Benefits:**
- Elimination of out-of-specification products
- Improvement of production efficiency by significant savings of syrup and $CO_2$
- Quick identification of production problems
- Traceable quality, automatic storage and recording of all relevant data

### 5.2. Quality control of syrup

For the determination of the original sugar content in the syrup (°Brix-fresh) or the glucose and fructose concentration at complete inversion (Brix-inverted) a **DSRn density and sound velocity transducer** with **mPDS 2000V3** evaluation unit is used.

**Benefits:**
Syrup quality is continuously monitored at every stage of sugar inversion.

Basis for the correct mixing ratio of syrup with water for soft drink production.

## 6. Technical Data

**Measuring range**

| | |
|---|---|
| Sugar: | 0 to 80 °Brix , 0 to 200 %Diet |
| Temperature: | 0 to 105 °C |
| $CO_2$: | 0 to 10 Vol (= 0 to 20 g/l) |
| Temperature: | -5 to 30 °C |
| Max. pressure: | 10 Bar |
| Max. sample temperature: | 121 °C |

**Ambient condition:**

| | |
|---|---|
| Temperature: | 0 to 35 °C |
| humidity: | 10 to 90 %, not condensed |

## 7. Measuring accuracy

- **Density and sound velocity**

  Based on density and sound velocity measurements, the Cobrix3 multibev determines the sugar concentration with an accuracy of **± 0.02 °Brix** and the diet concentration with typical accuracy of 0.5 % Diet.

- **$CO_2$ content**

  The accuracy in $CO_2$ determination is limited to **± 0.025 Vol (= 0.05 g/l)** due to varying sample compositions.

## 8. Summary

Anton Paar equipment provides continuous and automatic measurement of °Brix-fresh, °Brix-actual, % Diet and carbon dioxide content directly on the soft drink production line. High accuracy and repeatability as well as long-term reliability are guaranteed.

Over the years Anton Paar equipment has become a standard in on-line beverage quality control.

## 9. References


[1] "On-line Density Measurement in the Soft Drink Industry", Anton Paar Process application note

[2] (a) "Determination of the concentrations of soft drinks containing sucrose taking into account the sugar inversion", H. Stabinger, H. Heimel, S. Reichenpfader, E. Zwangsleitner, Mitteilungen aus dem Labor für Meßtechnik 3-10/1991.
(b) "°Brix Measurement on Soft Drinks Using the Anton Paar DSA 48", Test Report Swiss Lab, 1995.

[3] "Density Measurement in the Soft Drink Industry",
Anton Paar Lab application note

[4] M. Rammert, M. H. Pahl, Die Löslichkeit von Kohlendioxid in Getränken, Brauwelt **12**, 488 - 499