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Anton Paar

Process Application Note

On-line Density Measurement in the Soft Drink Industry

1. Introduction

For centuries people have tried to quench their thirst with a variety of drinks.
Additives of different types such as fruit concentrates, spices, acids and salts in combination with sweeteners and carbon dioxide have helped to “improve the quality of water as a thirst-quencher” and have led to a great number of soft drinks.

Due to the increase in soft drink production and consumption over the last few centuries, the standards for quality control have been refined [1, 2, 3].
Certain parameters (e.g. the sugar content) are checked for purposes of production control.
Finished products are analyzed to ensure that they comply with legal requirements and other internal quality regulations drawn up by the soft drink producer.

Anton Paar offers reliable equipment for on-line and laboratory quality control of soft drinks that is successfully used by many soft drink producers worldwide.

2. Production of soft drinks

Figure 1 shows a short schematic outline of the soft drink production process.

Carbonated soft drinks are produced by mixing

- **water,**
- **syrup** and
- **carbon dioxide.**

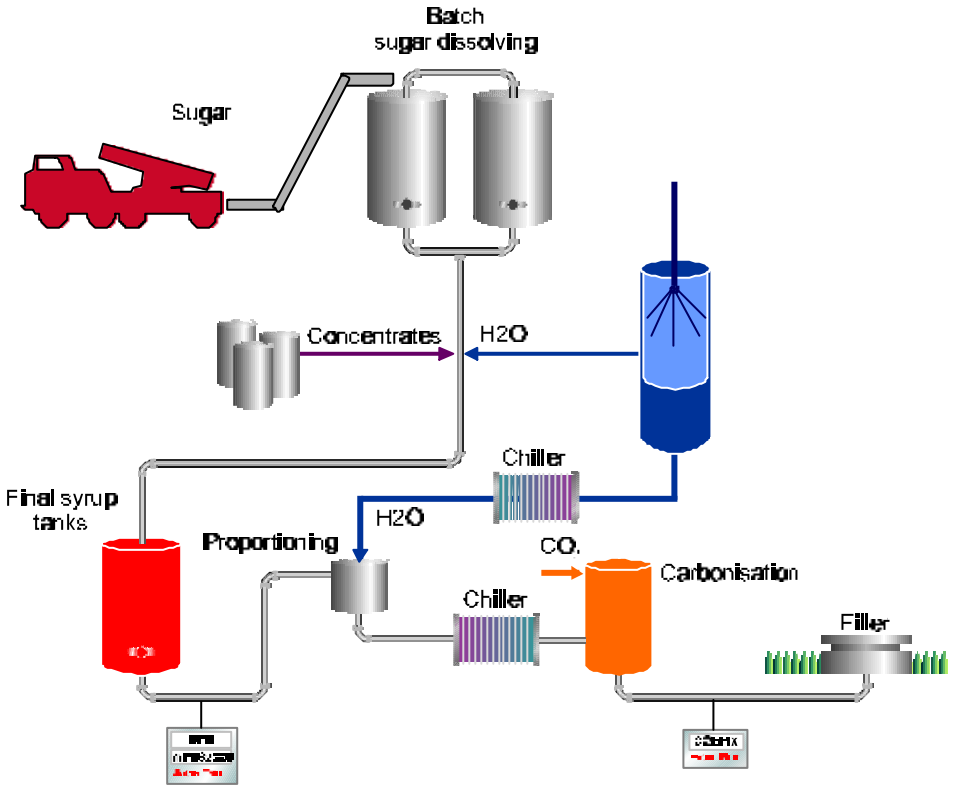

Fig. 1 Outline of the soft drink production process

Water

Since the general basis of soft drinks is **water**, is a major concern in terms of quality.
Water treatment is therefore the first stage in producing soft drinks of any kind.
To remove the oxygen, the process water is deaerated by flushing with carbon dioxide. Oxygen causes ageing in soft drinks and decreases the stability.

Syrup

The most expensive component of a soft drink is the **syrup.** The syrup contains small amounts of different ingredients such as flavors, acidulants, preservatives or colors, the main constituent is the sweetener.

The relative sweetness of different sweeteners used for soft drink formulations is given below [1]:

Sucrose	1
Glucose	0.5 - 0.8
Fructose	0.8 - 1.7
Artificial sweetener:	
Acesulfame K	110 - 200
Aspartame	120 - 215
Cyclamates	30 - 140
Saccharine	300 - 700

„Sugar“ (= saccharose = sucrose) is the traditional sweetener in the production of soft drinks and is derived from cane or beets. A typical syrup contains approx. 60 to 70 % w/w of sugar.

In western countries **high fructose corn syrup** (= **HFCS** = iso-syrup) has increasingly replaced sugar as the sweetener for soft drinks. HFCS is a mixture of mainly fructose and glucose and has a slightly higher sweetening effect than sucrose (see below). There are various mixtures of HFCS used for the production of soft drinks which differ in fructose concentration (42%, 55% and 90%).

The increasing health-consciousness of consumers has caused soft drink producers to produce low-calorie beverages.
These so called diet (or light or sugar-free) soft drinks contain **artificial sweeteners** with a sweetening effect many times higher than that of sucrose.

Due to their high sweetening effect, artificial sweeteners can be used in very low concentrations which are in the same order of magnitude as the other ingredients such as acidulants, caffeine, colors, preservatives, etc. [3, 4]. To produce the final syrup, the corresponding sweetener is mixed with special additives and water.

The final syrup is then mixed with water in the correct mixing ratio and the product is carbonated either simultaneously or afterwards.

The finished product (soft drink) is filled into glass bottles, PET bottles or cans.

3. On-line measuring principle

3.1 Density measurement

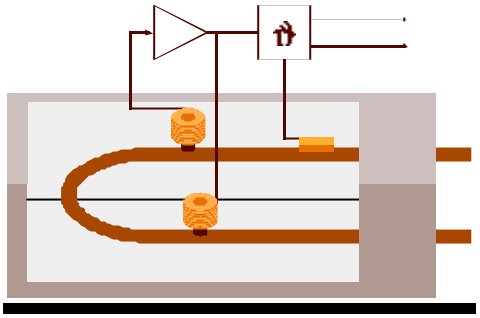

Fig. 2 Principle of density measurement with the DPRn

The Anton Paar process density transducers work according to the oscillating U-tube technique.
The U-shaped sample tube is made of Hastelloy.
The tube 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.
Oscillation period and sample temperature are measured and transferred to the evaluation unit. The temperature compensated density and the °Brix are then calculated with high accuracy.

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

3.2 Carbon dioxide measurement

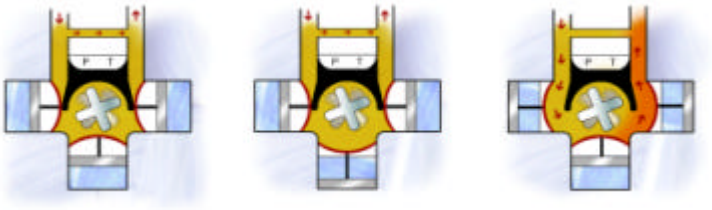

Fig. 3 Measuring principle of the CARBO 2100

The method of CO_2 concentration determination 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 into a small measuring chamber. A special degassing device brings the chamber pressure to the corresponding saturation pressure within a few seconds. The saturation pressure and the temperature of the sample are measured and the amount of dissolved CO_2 is calculated. The influence of CO_2 on density is then compensated. The measurement is repeated every
12 seconds.

4. Quality control in the soft drink industry

To guarantee constant product quality, the recipe for a specific soft drink must be strictly adhered.

The recipe is usually based on a sucrose (or sweetener) concentration.
Since the concentration can be precisely measured using density, the density measurement is an important quality control parameter during soft drink production:

- The sugar (or sweetener) content of the syrup must be known to calculate the correct mixing ratio of the syrup with water.
  The sugar concentration in **% w/w sucrose** in an aqueous solution is called **°Brix**.

- To ensure constant product quality, the sugar concentration in the finished product is analyzed.

- The concentration of the artificial sweetener in diet syrups and diet soft drinks has to be monitored for quality control purposes.
  The concentration of diet beverages is usually expressed in **% Diet** or in °Brix**.**
  % Diet describes how close the measuring result is to the target value. The classic methods for determining % Diet in the laboratory are the colorimetric phosphate method for cola beverages (spectrophotometric method) and the titration of acids (citric acid) for other beverages.

In the quality control of sugar-based soft drinks, the "sugar inversion" is a severe problem. The determination of sugar content in inverted soft drinks using density and sound velocity measurement is discussed in Anton Paar's application report "Sugar Inversion and Brix in Soft Drinks: COBRIX$_2$ Measures Both!" [5].

4.1. Process QC of soft drinks

Anton Paar offers different density measuring devices for on-line quality control of syrup and finished products during soft drink production:

4.1.1. COBRIX$_2$ beverage analyzer

The COBRIX$_2$ is a "ready to install" system especially designed for the soft drink industry.

COBRIX$_2$	
consists of	• a **DPRn density transducer** for density measurement, • a **mPDS 2000** evaluation unit for the DPRn, • a **CARBO 2100** for carbon dioxide determination and • the **DAVIS** software.
measures	density, carbon dioxide (CO_2) temperature
performs	automatic temperature and CO_2 correction of density
determines	• **°Brix of regular soft drinks** • **%Diet or °Brix of diet soft drinks** - **Carbon dioxide in the bottle/can**

- The COBRIX$_2$ is a compact system with all its components (DPRn, CARBO 2100, mPDS 2000, valves, pump,…) mounted onto a rack. Within one day the system is installed and ready to go.
- The compact design of the COBRIX$_2$ guarantees optimal measuring conditions (constant flow rate,…).
- The COBRIX$_2$ 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.
- For the analysis of inverted soft drinks a special COBRIX$_2$ version for sugar inversion is available.

4.1.2. DPRn with mPDS 1000 or mPDS 2000

The quality control of soft drinks can also be performed using single components such as the DPRn density transducer in combination with a CARBO 2100 and an mPDS 1000 or mPDS 2000 evaluation unit.

DPRn	with mPDS 1000/mPDS 2000
measures	density, temperature CO_2 (measured with the CARBO 2100).
performs	automatic temperature (and CO_2) correction of density
determines	• **°Brix of regular soft drinks and syrups**

- The different components (DPRn, CARBO 2100, mPDS 1000 or mPDS 2000) have to be installed separately.
- The DPRn with evaluation unit provides the current measuring result.
- Selection between different products is possible.
- The DAVIS software can be used as an option.

4.2. Laboratory QC of soft drinks

Many QC laboratories in soft drink producing plants use the Anton Paar density meters **DMA 4500** or **DMA 5000** in combination with the **sample changer SP-1m**.
Carbonated products need to be degassed before measurement, preferably with the **degassing station for soft drinks** by Anton Paar.
See our lab application note „Density Measurement in the Soft Drink Industry“ [6] for more information.

5. Application sites and benefits

5.1. Syrup production

For the determination of sugar content in the syrup, DPRn density transducers with a mPDS 1000 or mPDS 2000 evaluation unit are used.

Benefits:
- Optimum sugar concentration in the syrup is achieved.
- Syrup quality is continuously assured.
- Highly cost-effective syrup production.
- Basis for the correct mixing ratio of syrup with water for soft drink production.

5.2. Filler

The on-line quality control of finished soft drinks can be performed with the COBRIX$_2$ beverage analyzer. °Brix or %Diet concentration and the CO_2 content are continuously monitored to assure constant product quality.

Benefits:
- Elimination of out-of-specification products.
- Decrease in production costs.
- Improvement of production efficiency by significant savings of syrup and CO_2.
- Quick identification of production problems.

Anton Paar on-line transducers are successfully used at:

Coca Cola Erfrischungsgetränke, Germany
Coca Cola, USA
Coca Cola Amatil, Australia/New Zealand
Pepsi Cola,
and many others.

6. Measuring range

COBRIX$_2$ and DPRn transducers:

Concentration: 0 to 85 °Brix
0 to 2 °Brix
0 to 100 %Diet
Temperature: 0 to 105 °C

The conversion of density and temperature into °Brix concentration is based on tables from the ICUMSA (*International Commission for Uniform Methods of Sugar Analysis*).

CARBO 2100:

CO_2 content: 0 to 10 Vol (= 0 to 20 g/l)

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.
On request customer specific tables or formulas can also be used in the CARBO 2100.

7. Measuring results – accuracy

- **Density**

  For the COBRIX$_2$ and DPRn transducers the accuracy in sugar concentration is **± 0.02 °Brix**

  Artificial sweetener concentrations in diet soft drinks are very small, usually in the range of 0.25 to 1.0 °Brix.
  The quality control of diet soft drinks requires the detection of small density changes.
  The precision of density measurement must therefor be enhanced by accurate CO_2 measurement and compensation, the use of narrow band concentration tables and temperature maintenance near steady state.

  Under such conditions, the accuracy in concentration of diet beverages increases to **± 0.0025 °Brix** or **± 1.0 % Diet** in the range of 0 to 2 °Brix.

- **CO_2 content**

  The accuracy of the CO_2 result depends on the solubility of CO_2 which is influenced by temperature and sample composition.
  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 on-line equipment provides continuous and automatic measurement of °Brix, %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 density measuring devices have become the standard in on-line beverage quality control.

9. References

[1] „Sugar Technologists Manual“, published by Bartens Verlag, 8th edition, 1995

[2]
(a) Handbook "Alkoholfreie Erfrischungsgetränke“, Südzucker - Frankenzucker, 3rd edition, 1987, Oberursel, Germany
(b) "RSK-Werte“, Verband der deutschen Fruchtsaftindustrie, published by Verlag Flüssiges Obst GmbH, 1st edition, 1987

[3] Soft drinks, part II, Don Blenford, Ingredients and Analysis International, Feb./March 1997, p. 25

[4] „Herstellung, Eigenschaften und Anwendungen von Süßungsmitteln in Lebensmittel“, T. Niederauer, Brauwelt, 1995, Nr. 30, 1454

[5] „Sugar Inversion and Brix in Soft Drinks: COBRIX$_2$ Measures Both!“, Process application note, Anton Paar GmbH

[6] „Density Measurement in the Soft Drink Industry”, Lab application note, Anton Paar GmbH