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Process Application Report

In-line Wine Monitor: Alcohol and Extract Determination in Finished Wine using Density/Sound Velocity

1. Introduction

Grape wine after fermentation consists of alcohol, extract, CO2 and water. In order to determine the concentrations of these components two suitable physically independent properties of the wine have to be measured. Methods such as distillation and density or refractive index and density have been applied to determine the exact composition.

This report describes a new, very accurate and fast on-line method for the measurement of alcohol and extract in wine - the use of density and sound velocity measurement, combined with CO_2 determination. The same technology has been applied very succesfully to determination of alcohol, extract and Original Extract in beer for more than 10 years.

The COBRIX complete beverage analyzer is now available with a special "wine software module", extending its capabilities from measurement of softdrinks, beer and alcoholic lemonades to wine and sparkling wine.

The Cobrix system combines a DSRn density/sound velocity transducer with the new Carbo2100 CO_2 transducer, incorporated into a complete system with process control unit, sample pump, and the Windows-based software package DAVIS.

2. Measuring principle

Density/Sound velocity measurement:

The DSRn 427 density/sound velocity transducer consists of a U-tube density meter with integrated sound velocity sensor (Fig. 1).

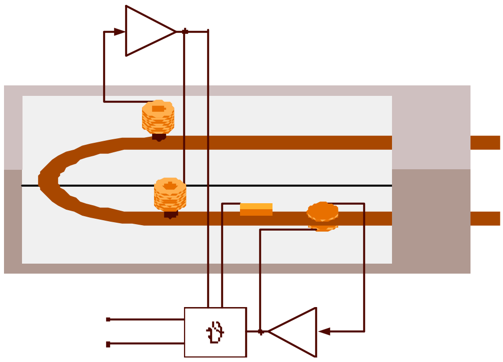

Fig. 1: DSRn 427 density/sound velocity transducer

The density of the wine is determined by measuring the period of oscillation of the oscillating U-tube.

The sound velocity is measured over a fixed distance between a transmitter, generating ultrasonic pulses, and a receiver. The propagation speed is determined with a repeatability of 0.01 m/s.

Both the density of the sample and the propagation speed through the sample change with temperature, therefore it is necessary to measure the temperature directly at the U-tube with high precision.

CO_2 Measurement:

The Carbo 2100 CO_2 Analyzer is based on the temperature/pressure principle at equilibrium pressure:
According to Henry's Law the concentration of dissolved gas in a liquid is directly proportional to the pressure of the gas in equilibrium with the liquid.
The Carbo 2100 is the second generation of Anton Paar's CO_2 sensors with focus on long service life and fast drift-free measurement.

3. The wine nomogram

When measuring the density of alcohol/water mixtures, the density decreases with increasing alcohol concentration, but the sound velocity increases (Fig. 2).

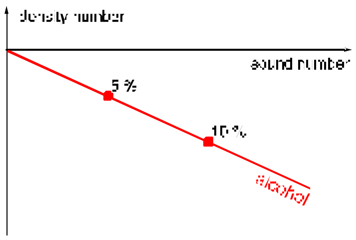

Fig. 2: Alcohol curve

On the other hand, increasing sugar concentration increases both density and sound velocity. Since the extract of wine is not only sugar but a mixture of various sugars, acids and other substances, the extract curve will not coincide with the sugar curve (Fig. 3).

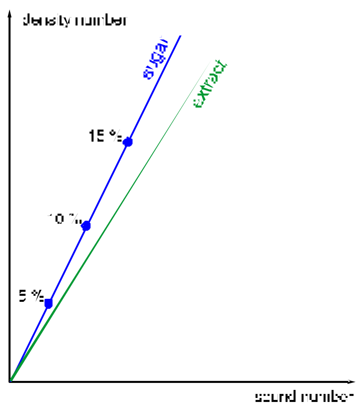

Fig. 3: Extract curve

Combining the alcohol and extract curves in a system of co-ordinates yields a plane between the alcohol and extract curve which covers all alcohol/extract/water mixtures (Fig. 4). By measuring density and sound velocity of a large variety of wines covering the complete concentration range, and correlation with the alcohol and extract concentrations (determined by a reference method), concentration formulas were established. These formulas are programmed into the COBRIX$_2$ beverage analyzer.

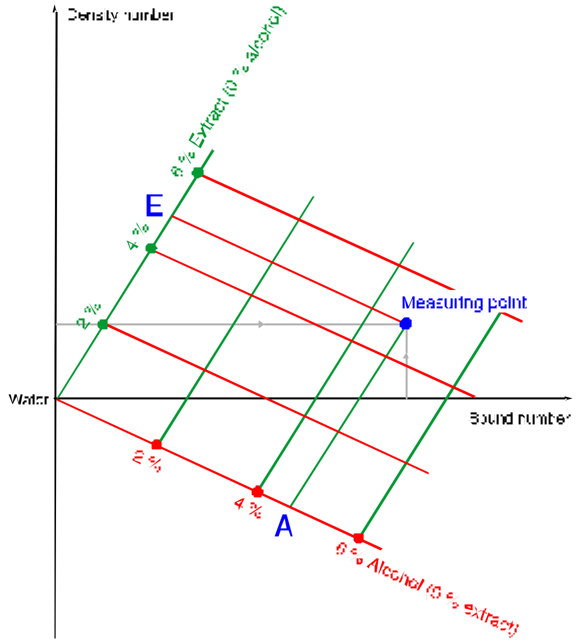

Fig. 4: Nomogram for wine analysis

For in-line process applications, instead of the graphical nomogram a set of polynomial formulas is used, which also take into account the temperature dependence.
The wine software module automatically calculates alcohol and extract content from density, sound velocity and temperature. The formulas are valid for the entire concentration range of red and white table wines as well as sparkling wines.

4. Instrumentation - example of a typical installation

A typical installation site is just before the filler (Fig. 5).

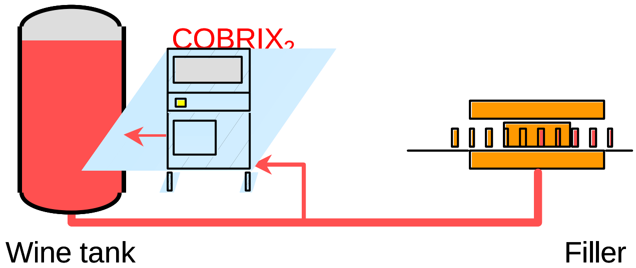

Fig. 5: Cobrix Wine Monitor

The $COBRIX_2$ system can store up to the product specifications of up to 255 different products (wines), with alarm limits for each product.
The optimized configuration performs very well also during frequent filler-stops or product changes

5. Measuring range

Temperature	5 to 25 °C
Alcohol content	0 to 20 % v/v
Extract	0 to 20 g/100ml
CO_2 Content	0 to 20g/l (0 to 10 vol)

6. Accuracy of the density/sound velocity method

To achieve highest accuracy it is necessary to make separate adjustments for each wine type with regard to the laboratory reference method. A maximum of 255 different types of wine can be selected within the mPDS 2000V3 process control unit.

After the product specific adjustment the accuracy of alcohol and extract values depends on the accuracy of the instruments themselves and on the stability of a number of process and sample parameters.

- **Influence of the accuracy of density/sound velocity measurement itself:**

  With reference to the reproducibility of the transducers and their different effects on alcohol/extract values, the accuracies are yielded as follows:
  Alcohol: <0.01 % w/w
  Extract: <0.01 °Plato

  This influence is practically negligible!

- **Temperature:**

  Temperature coefficients valid for the temperature range 5 to 25 °C are stored in the mPDS 2000V3 process control unit.

  There is practically no temperature error, provided that there are no quick temperature changes (<1 °C/min).

- **Pressure:**

  The pressure in the main line should be high enough to keep CO_2 in solution, because gas bubbles interfere with the measurement. This will certainly be the case at line pressures greater than 1.5 bar.

  Average change per bar:
  Alcohol: <0.01 % w/w
  Extract: <0.01 °Plato

- **Extract composition:**

  A change in the extract composition mainly affects the sound velocity and thus the alcohol content. This error also depends on the extract content itself.

  Test measurements have shown the following values:
  Alcohol: 0.03 % w/w
  Extract: <0.01 °Plato

  Depending on the individual wine type, these values can vary considerably.

- **CO_2 content:**

  The dissolved CO_2 influences both the density and sound velocity. The influence of the average CO_2 content is appropriately corrected by the Carbo 2100 CO_2 Analyzer.

  In general practice, the CO_2 content of a special wine type can fluctuate by up to ±0.2 g/l CO_2 around a target value of e.g. 1 g/l. Typical white wines have CO_2 concentrations of 0.8 to 1.2 g/l.

- **Total accuracy:**

  According to the law of propagation of error we obtain the following total accuracy:

  Alcohol: 0.02 % w/w
  Extract: <0.02 °Plato

7. Application sites - benefits

- **Before the filler:**

  The COBRIX$_2$ In-line Monitor is used to determine the alcohol, extract and CO_2 content before the filler, as well as line pressure and line temperature.

  This measurement is useful for
  - continuously monitoring wine quality
  - separating first and last runnings
  - interface detection.

  Benefits:
  - Wine quality is continuously assured.
  - Different wine types are exactly separated

8. Summary

The well proven density/sound velocity method provides a highly accurate measurement of the alcohol and extract content. The main constituents alcohol/water and extract/water are mathematically separated and the concentration values are determined.

The effects of variation of temperature, and CO_2 concentration on the measured results are well compensated.
Further it is worthwhile to mention that the COBRIX$_2$ In-line Monitor could even be used for the measurement of "non-alcoholic" or "low-alcoholic" wines.

For applications where complete quality control is required, the COBRIX$_2$ allows for the connections of additional sensors for dissolved oxygen, pH, conductivity and colour.

9. References

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[3] MURER, G.: "Stammwürze: In-line-Bestimmung durch Schallgeschwindigkeit", Brauindustrie 3/89, page 278-282

[4] BLODER, J.: "In-line Erfassung des Alkohol-, Extrakt- und Stammwürzegehaltes von Bier", Brauindustrie 3/92, page 214-217

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