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# Fermentation Monitor QWX43

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## How „accurate“ is „accurate“ and how can the Fermentation Monitor QWX43 from Endress+Hauser help to make precise statements about fermentation in order to automate the process?

The determination of important parameters in the fermentation of wort to beer, such as the extract value or alcohol content, is mainly carried out in traditional breweries by laboratory measurements. These play a central role and sampling is usually part of the daily routine. The samples are either tested on site using hand-held measuring devices or, if a more precise statement on fermentation control or release is required, analyzed in the laboratory.
In the laboratory, the analysis is usually carried out with devices that use a combination of NIR technology to determine the alcohol concentration and high-precision density measurement for sugar determination. The accuracy of these measurements is crucial, as without direct inline measurement in the tank, it forms the basis for numerous decisions and developments, from controlling the fermentation process to quality control.
The precision of laboratory measurements depends not only on the instruments used, but also on various factors such as the calibration and maintenance of the measuring equipment, the qualifications and experience of the operating personnel, the environmental conditions and the methodology and protocols used for the measurements. If the laboratory results are to be compared with the measurements of the Fermentation Monitor QWX43 directly in the fermentation tank, it is essential to take these influences into account in order to make well-founded decisions. Figure 1 illustrates this situation.

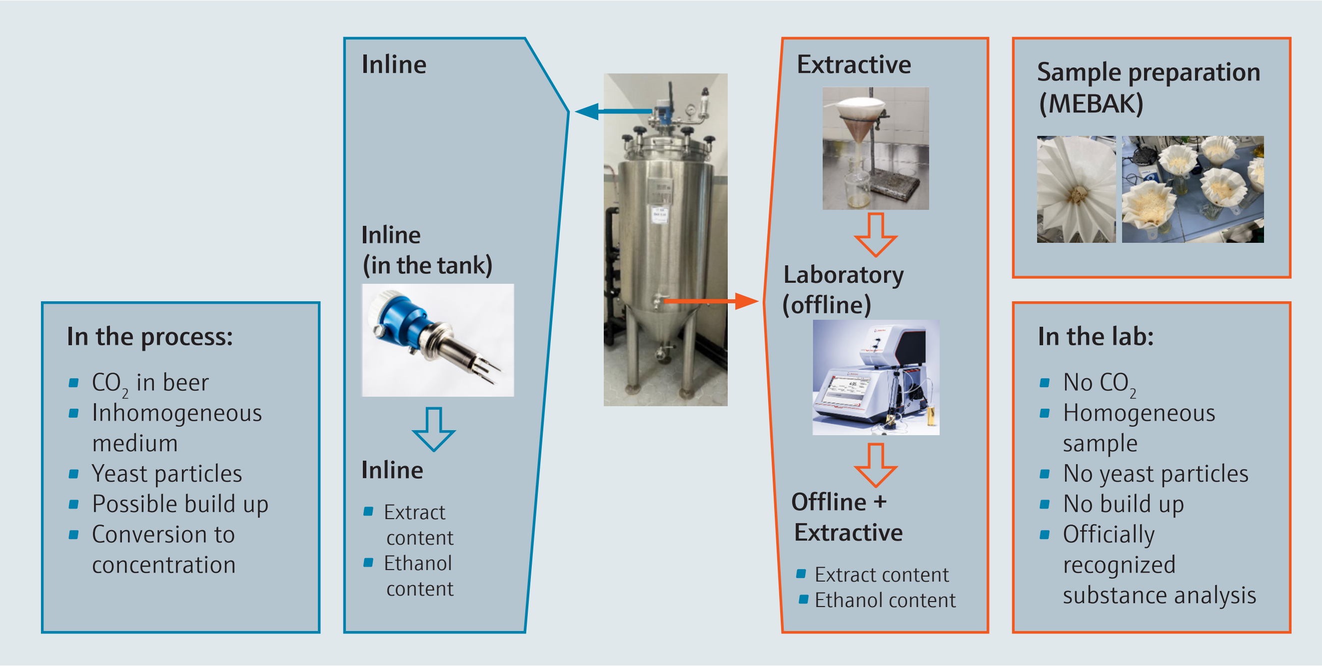


Figure 1: Comparison of inline and laboratory measurement for beer – schematic

This white paper focuses on the influences of laboratory sample preparation on the laboratory measurement result and shows how these can be optimally compared and verified with the inline measurement values of the Fermentation Monitor QWX43. Various study results are used and explained. In addition, the use of the process data measured in the fermentation tank for optimal fermentation control is discussed.

## What does laboratory sample preparation normally look like and which steps can significantly influence the measurement result?

The method catalog of the Central European Brewing Analysis Commission (MEBAK) describes the necessary sample preparation for the measurement of extract and alcohol concentrations in the laboratory using a combination of NIR and density measurement.

To prepare the sample for an undisturbed laboratory measurement, the $CO_2$ present in the sample must be removed. In addition, it must be ensured that the sample is free of turbidity. According to the instructions, the $CO_2$ produced during fermentation is expelled by repeated shaking and subsequent depressurization of the sample vessel. The turbidity should be removed by filtering the sample solution. In practice, these two steps are often combined in one step by filtering the sample through a filter paper with a small pore size, to which diatomaceous earth is also added to remove the $CO_2$.

Ideally, the sample must be filtered until it is completely clear so that the laboratory device can ensure a reliable and repeatable measurement via NIR. However, the steps described above significantly change the original sample. The removal of the gaseous $CO_2$ ensures that other volatile components of the sample, such as the alcohol, are also entrained in small quantities and disappear from the sample. For this reason, the alcohol laboratory reading is typically slightly lower than the alcohol concentration measured directly in the tank. This phenomenon is often found when comparing the laboratory measurement data with the inline devices in the fermentation tank.

A further effect can be observed in the extract concentration measured in the laboratory. During an evaluation of empirical data, it was found that in some cases the sugar concentration in the laboratory sample apparently increased compared to the inline values of the Fermentation Monitor QWX43. In contrast to the described evaporation at the alcohol concentration, however, this behavior of the sample does not seem to occur with every sample. From the empirically determined results and numerous practical examples, it can be assumed that the final extract concentration determined in the laboratory depends on factors such as the type of beer or the filtering behavior of the yeast used.

In practice, the results of the comparative data suggest that the removal of $CO_2$ during sample preparation and thus the unintentional removal of some of the alcohol appears to be the main effect. This can be reliably corrected using suitable compensation algorithms so that the inline measured value of the alcohol concentration in the tank matches the release limits that were defined using the laboratory measurements. Suitable compensation algorithms are provided in the Fermentation Monitor QWX43 to facilitate the comparison of the inline measured values of the device with the laboratory measured values.

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## Comparison of inline and laboratory measurements

### Effects of insufficient filtering of the laboratory sample or general scattering of laboratory measurement values with prescribed sample treatment:

However, an effect on the laboratory measurement due to insufficient filtering cannot be compensated for using compensation algorithms. Here, the sensors in the laboratory do not react in a repeatable manner. However, the user should be aware of the resulting phenomenon, as an insufficiently filtered sample can suggest a supposedly high deviation between the two measured values when comparing the inline measurement with the laboratory result. Normally, the user would give greater credibility to the laboratory measured value, which in the situation described can lead to a seriously incorrect decision, as the laboratory measured value is heavily distorted by the inadequate filtering.
In general, however, it can be said that even with proper filtering and sample handling as well as the prescribed maintenance and calibration of the laboratory equipment by the manufacturer, the laboratory measurements show a certain amount of scatter, which must be taken into account in a comparative assessment. Figures 2 to 4 illustrate this spread. In the laboratory test, four samples were taken from a bottle of filtered finished beer, each of which was divided into three parts after filtering and degassing and measured independently of each other in the laboratory device, which uses a combination of NIR and density measurement.

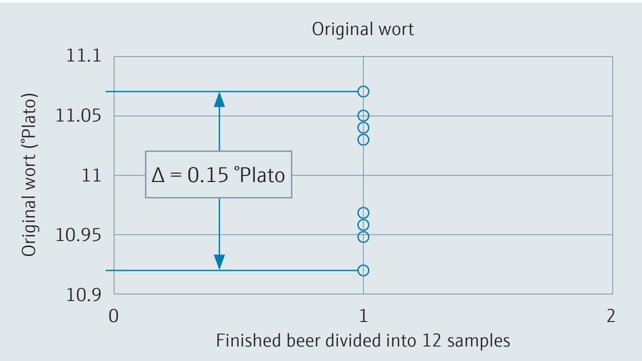


Figure 2: Scattering range of the measured original wort under 12 measurements of a filtered and degassed clear finished beer (Pilsener type)

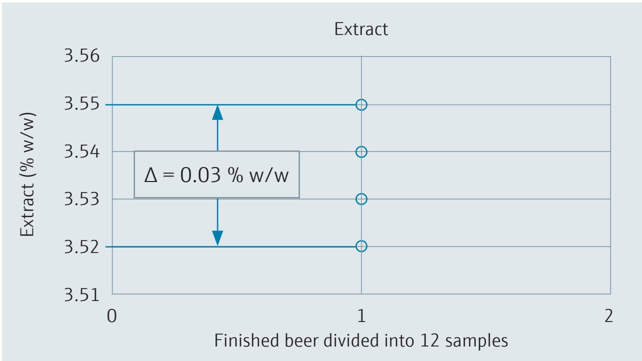


Figure 3: Scatter range of the measured extract value (real/apparent) among 12 measurements of a filtered and degassed clear finished beer (Pilsener type)

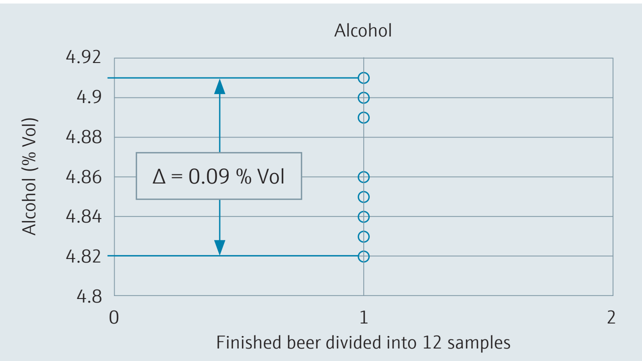


Figure 4: Scattering range of the measured alcohol value under 12 measurements of a filtered and degassed finished beer (Pilsener type)

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Non-linearities in the measurement: Both methods, inline and laboratory measurements, can exhibit non-linearities. In inline measurements, these can be caused by uneven distribution of the medium and different gas contents, while in laboratory measurements, possible inhomogeneities of the sample itself can play a role. A non-linearity can be determined if the decrease in extract content in relation to the increase in alcohol content is not linear. This linear relationship can be seen as an example in Figure 5 and Figure 6. The deviations between the theoretically producible linear relationship and the actual measured values are the non-linearities illustrated by Fig. 7 to Fig. 9 in a direct comparison of >20 fermentation processes of different beer types.

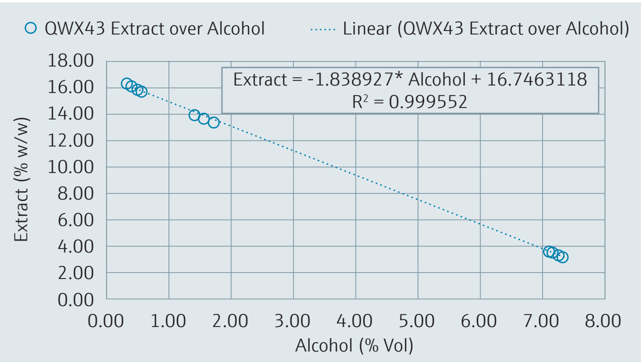


Figure 5: Non-linearity – correlation of a fermentation – measured with Fermentation Monitor QWX43

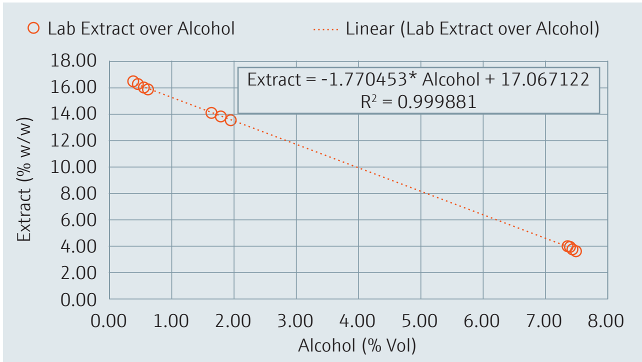


Figure 6: Non-linearity – correlation of a fermentation - measured with the laboratory measurement

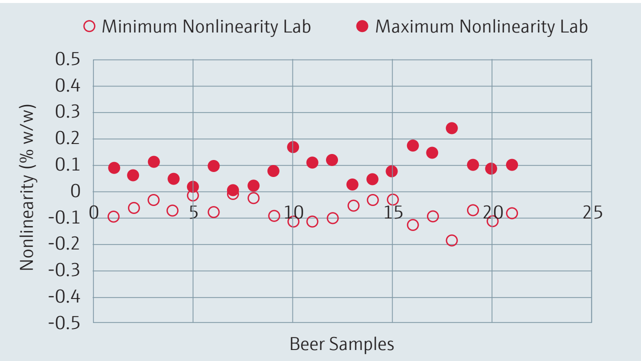


Figure 7: Non-linearity of the laboratory measurement over > 20 different fermentations of different beer types (laboratory measurement)

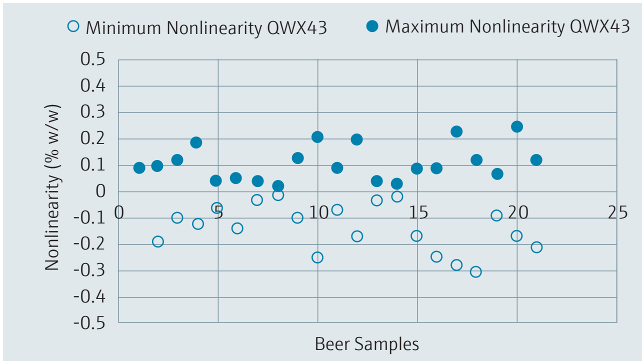


Figure 8: Non-linearity of the measurement inline by Fermentation Monitor QWX43 over > 20 different fermentations of different beer types (measurement using Fermentation Monitor QWX43)

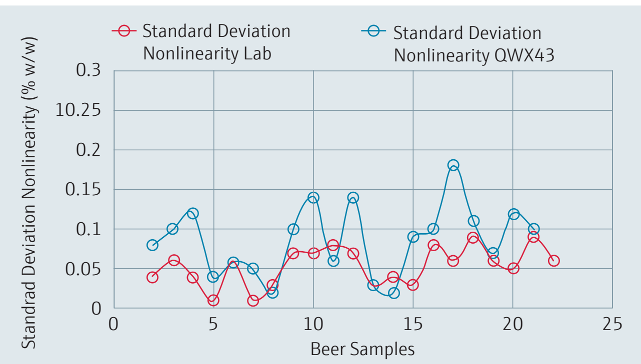


Figure 9: Direct comparison of the standard deviations of the non-linearity of both methods via the measurement of > 20 different fermentations

## Congruence between inline and laboratory measurements

With the Fermentation Monitor QWX43, Endress+Hauser has developed a device with multi-sensor technology that reliably measures the fermentation parameters during the fermentation process of clear wort from cereal malts or cereals to e.g. beer, analogous to the parameters determined in the laboratory, and outputs them for effective process control.

The Technical University of Munich (TUM) has the Weihenstephan Research Center for Brewing and Food Quality (BLQ) at its Freising site within the TUM School of Life Sciences. This institute has examined the measured values of the Fermentation Monitor QWX43 in comparison with measured values determined in the laboratory. The „Alcolyzer DMA 5000M“ control measuring device from Anton Paar was used.

The test method that was followed as a comparison was:
„B-590.10.181 Original wort, extract and alcohol - Biegeschwinger and NIR“ MEBAK online method B-590.10.181 Rev. 2020-10 Mitteleuropäische Brautechnische Analysenkommission (MEBAK ®) e.V., Freising, Germany

A 200 L fermentation tank was used for the fermentation test series, in which the Fermentation Monitor QWX43 was installed. The wort used varied between bottom-fermented and top-fermented wort, which was fermented with yeast of the TUM® 34/70 strain. Numerous tests showed good congruence between the laboratory measurements and the inline measurements of the Fermentation Monitor QWX43. To increase user confidence in the inline measurement, the compensation algorithms of the Fermentation Monitor QWX43 can be used.

A few of the corresponding comparative series between laboratory and process measurements can be seen in figures ten to twelve.

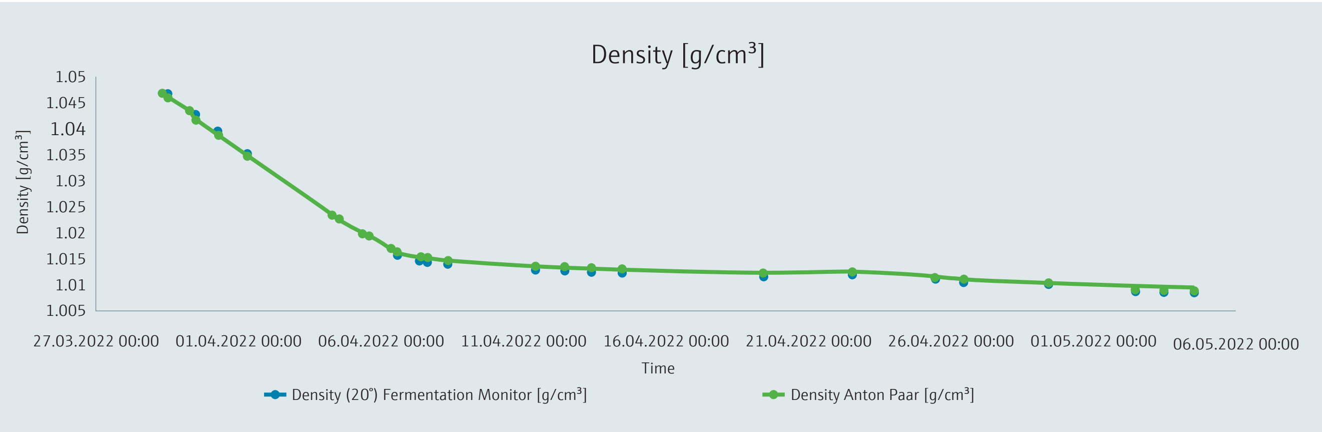


Figure 10: Comparison of the basic measured variable „density“ between Anton Paar Alcolyzer and Fermentation Monitor QWX43 in a fermentation test with top-fermented wort (source: Report TUM)

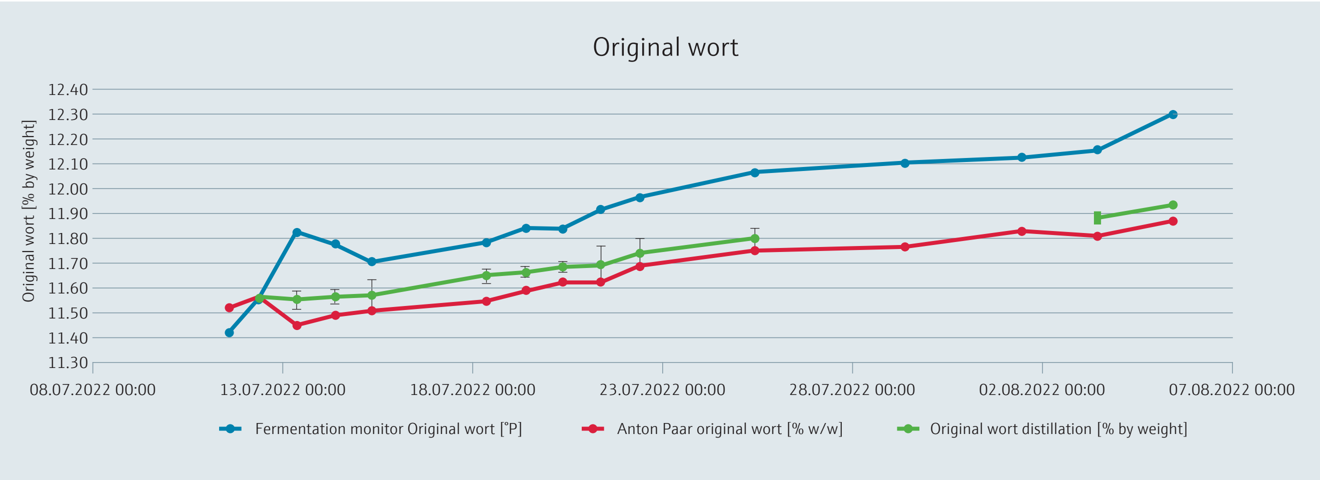


Figure 11: Comparison of the original gravity calculation with Anton Paar Alkolyzer laboratory measurement, laboratory determination by distillation and fermentation monitor QWX43 during a fermentation test with bottom-fermented wort (source: Anton Paar Alkolyzer): Report TUM)

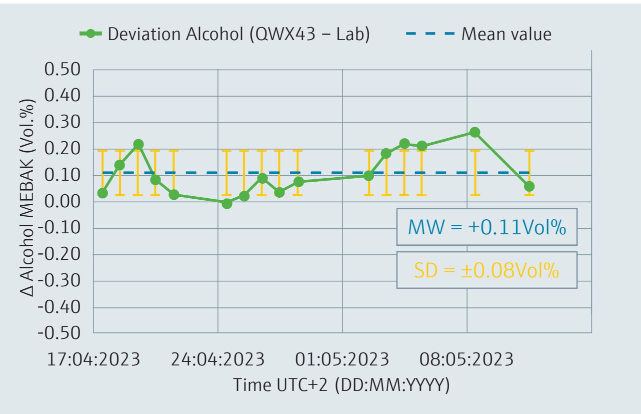


Figure 12: Deviations between laboratory measured value and inline measurement for alcohol in %Vol, if the compensation algorithms for sample preparation in Fermentation Monitor QWX43 are used

Inline and laboratory measurements were also compared with a distillation process to determine the alcohol content. This showed that both the laboratory device with the NIR measurement directly related to the alcohol content and the fermentation monitor showed on average only very small deviations from the distillation value. The laboratory device showed an average deviation of 0.09% vol alcohol from the distilled value and the fermentation monitor QWX43 an average deviation of 0.125% vol alcohol. This means that the measurement results of the two methods are only slightly different.

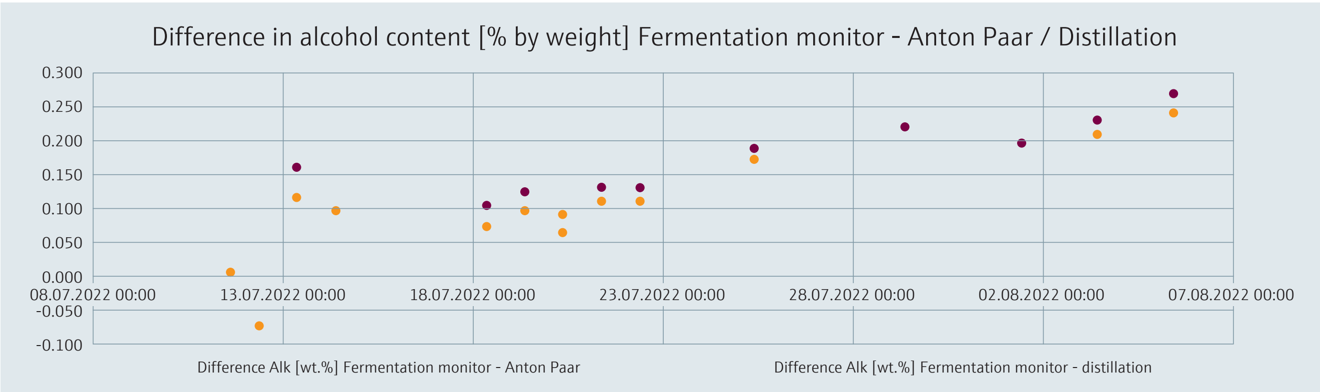


Figure 13: Comparison of Anton Paar Alcolyzer DMATM 5000M and Fermentation Monitor QWX43 alcohol measurements with the distillation method (source: TUM report)

## The overall evaluation and assessment of the tests by the BLQ of the Technical University of Munich resulted in the following assessment:

„The comparison between the laboratory measurement and the inline measurement shows, based on statistical analysis, that there was a significant but very small difference between the measurements. For the measured variable alcohol (%vol.), the measured differences between laboratory and inline measurement are on average +0.11 %vol. The standard deviation of this measurement is ±0.09 %vol. For the measurand apparent extract (°Plato), the differences measured between laboratory and inline measurements averaged -0.13 °Plato. The standard deviation is ±0.08 °Plato.
When calculating the original gravity of both methods (inline and laboratory reference method), a mean value of +0.16 °Plato and a standard deviation of ±0.2 °Plato were determined.

The comparisons carried out at the Weihenstephan Research Center between the results of the accredited laboratory measurement and the measurements of the QWX43 inline monitor show that the QWX43 Fermentation Monitor is suitable for practical use in the automation of the fermentation process."

By using the compensation algorithms for the influence of sample preparation in the laboratory, the results obtained inline using the Fermentation Monitor QWX43 were even more in line with the laboratory results.

## Conclusion

As the brewmaster and the person responsible for the product and process quality of the beer, the users usually consult laboratory measurements, on the basis of which process control events such as tank bunging are approved. Laboratory measurements can be strongly influenced by the type of sample preparation, the possible inhomogeneity of the sample, the laboratory measuring device or the operator. The Fermentation Monitor QWX43 from Endress+Hauser offers a reliable alternative. The inline measurement values in the tank are independent of fluctuations due to differences in sample preparation or human handling and offer a high level of accuracy proven by independent test series. In order to reflect the influences of sample preparation in the laboratory and make the measured values more comparable, Endress+Hauser has developed compensation algorithms that can be applied to the alcohol content measured in the tank, for example.

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