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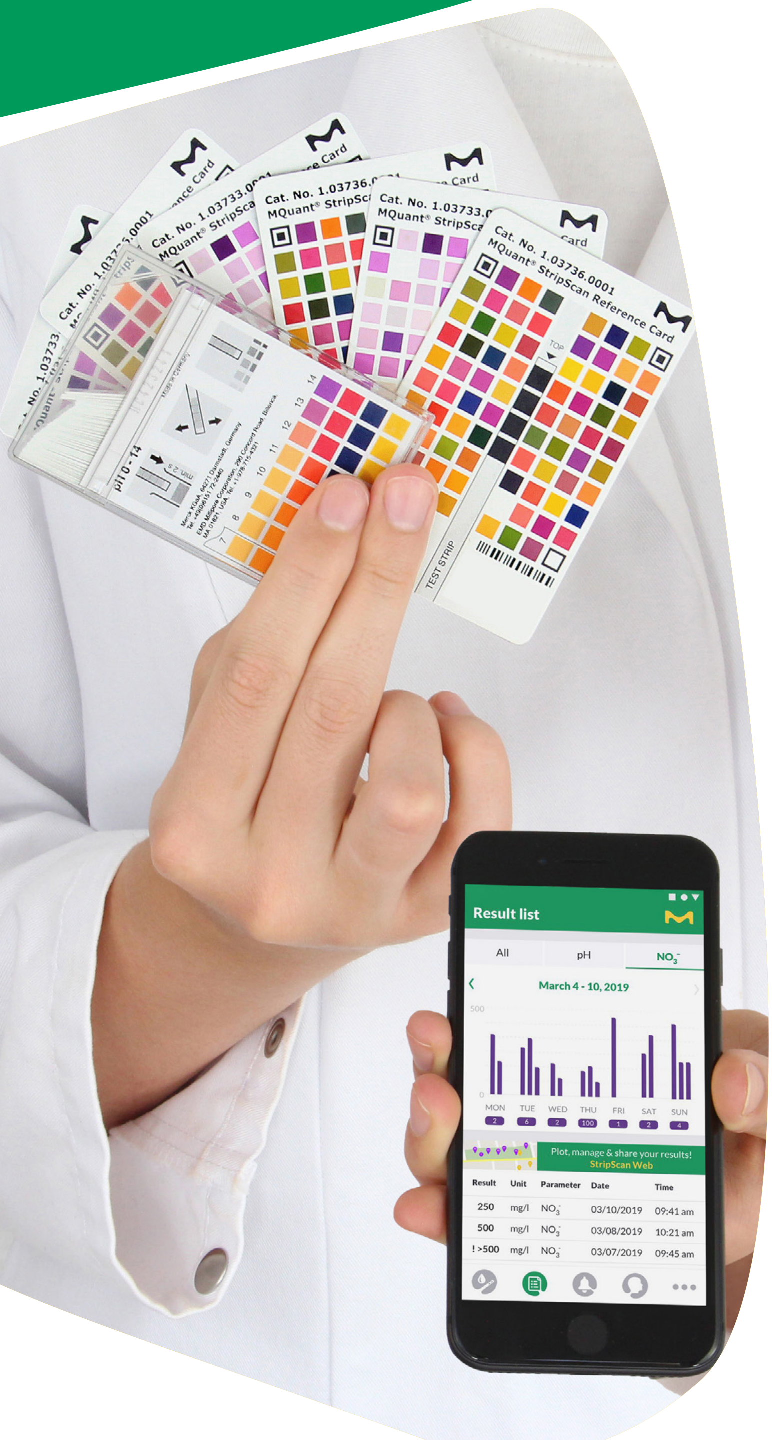

Beverage Testing with the MQuant® StripScan Mobile App

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Abstract

pH and nitrate content are two of the key parameters used to measure the quality and safety of food and beverages (F&B). Generally, pH measurements are carried out using pH strips, pH meters, or electrodes, whereas spectrophotometers or electrodes are used for measuring nitrate content. This article examines the use and efficiency of the MQuant® StripScan mobile app to measure the pH of orange juice samples and nitrate concentration of mineral water samples. The results indicate towards the possible use of the MQuant® StripScan mobile app as a viable alternative to more complex and instrument-based methods for pH and nitrate measurements in food and beverage analysis.

Introduction

Ensuring delivery of quality and safe food and beverage products is critical to the global F&B industry. pH plays an important role in preserving the color, flavor, texture, taste, and nutritional overall value of the product and significantly impacts the quality of final food and beverage product delivered. Moreover, maintaining the proper pH is a food safety issue.[1] For instance, keeping the pH of canned or preserved food at 4.6 helps prevent the growth of toxic bacteria, such as *Clostridium botulinum*.[2] Additionally, most microorganisms including bacteria, yeasts, and molds cannot survive or grow under very low or high pH values.

In the food industry, monitoring the pH of raw materials is essential to prevent their deterioration, which in turn, can affect the shelf-life of the final product. For example, in juices and brews, measuring the pH of water before addition in food processing guarantees a good quality and safe end-product.[3] This is particularly important when the water source is a municipal water system, where quality can vary considerably over time.

The traditional method for pH measurement involves the use of a pH meter, which uses the difference in electrical potential between a pH electrode and a reference electrode to generate a reading. The logarithmic nature of pH scale makes even a small change very significant, with even a change of just 0.3 units denoting doubling of acid concentration.[4] Additionally, pH measurements by electrodes are greatly influenced by factors like temperature, electrode stability (drift and hysteresis), the quality of the response slope/calibration curve, as well as the accuracy of the instrument.[5]

A novel method for measuring pH involves the use of the MQuant® StripScan mobile app in combination with test strips. This method provides pH measurements in a few seconds, and also offers additional benefits of automatic data storage, generation of graphs for further documentation, and an automatic data transfer to desktop devices.[6]

Nitrate ($NO3^-$) is another compound that has a significant influence on the quality of F&B products. Although it occurs naturally as part of earth's nitrogen cycle, various human activities contribute to its presence through agricultural operations (via excessive use of inorganic fertilizer), sanitation, diffusion from industrial processes, and disposal of solid waste.[7]

Consumption of food or beverages with high levels of nitrates can have adverse health effects. For example, it can generate carcinogenic nitrosamines upon reaction with amines or amides. Under some conditions, nitrates can also produce nitrite ($NO2^-$) through bacterial reduction in the stomach, causing a rare blood disorder called methaemoglobinaemia, a serious condition resulting from impaired oxygen transport by red blood cells.[8] For this reason, regulatory agencies have set safety limits for nitrate in food and beverages, as well as in water supplies. For example, the current acceptable daily intake (ADI) for nitrate set forth by the European Food Safety Authority (EFSA) is 3.7 milligrams per kilogram of body weight per day (mg/kg bw/day). The U.S. Environmental Protection Agency (EPA) has implemented a maximum contaminant level (MCL) for nitrate in water at 10 mg/L (as nitrogen; equivalent to 45 mg/L of nitrate).[9] The Food and Drug Administration's (FDA) allowable nitrate level in bottled water is the same as EPA, while in food, the level should not exceed 500 part per million (ppm) in the finished product.[10]

Different methods available for measuring nitrate content include spectrophotometric, chemiluminescence, electrochemical detection, chromatographic, capillary electrophoretic, and spectrofluorimetric methods.[11] Although these techniques offer high sensitivity and selectivity, they also involve laborious chemical work, and require specialized and expensive instrumentation. To address these issues, rapid detection techniques based on test strips are gaining popularity. Combined with the MQuant® StripScan smartphone app, test strips are fast, affordable, non-hazardous for most measurements, and do not require the handling of liquid chemical waste.

In this article, we describe the use of MQuant® StripScan mobile app and test strips for measuring pH and nitrate content of food and beverage products.

Methods and Materials

To measure pH and nitrate in F&B samples, MQuant® test strips (Merck KGaA, Darmstadt, Germany) were used; specifically pH test strips with the range 0-14 and nitrate test strips with the range 0-500 mg/L. The test strips were used according to manufacturer instructions, and readout was performed using the MQuant® StripScan app in conjunction with the appropriate reference cards (Merck):

1. Dip the test strip in the sample and select the parameter to measure (pH or nitrate) in the app.
2. As the app displays a countdown, remove excess sample from the strip and place the strip on the reference card.
3. Position the reference card within the mobile phone's camera view. Align the marks on the screen with the reference card. An image is acquired automatically, and the result is displayed immediately.

A. pH of orange juice

Four orange juice samples were analyzed using the MQuant® pH-indicator strips (pH 0-14) and the corresponding pH reference card. Five individual measurements were made for each sample.

The pH measurements using the test strips were compared with the measurements made using a pH meter.

B. Nitrate in mineral water

Three samples of mineral water were tested using MQuant® nitrate test strips (0-500 mg/L) and the corresponding reference card. Five measurements were made for each sample.

The nitrate measurements were compared with two different reference methods:

1. photometric determination using a Spectroquant® photometer
2. reflectometric determination using the Reflectoquant® system (reflectometer)

Results and Discussion

A variety of modern analytical techniques are being used to support the quality control of food and beverages. These include mobile photometry (e.g. Spectroquant® Move 100) or reflectometry (Reflectoquant® RQflex 20), bench top spectrophotometry (e.g. Spectroquant® Prove series), chromatography, mass spectrometry, NMR, X-ray analysis, and atomic spectroscopy.[5, 6] Although these techniques offer high sensitivity and selectivity, most of them also involve laborious chemical work and expensive investment in instruments.

Rapid detection techniques based on test strips are gaining popularity. A visual observation of color or fluorescence forms the basis of the test strip detection method. Typically, the test substance reacts with chemicals on the reaction pad(s) of the test strip and results in a color change, which is then compared with a color reference for validation.[12] One drawback of this technique, however, is that a semiquantitative readout is not very accurate, and is prone to individual variations and documentation errors. These aspects are addressed by a new app reader for test strips, the MQuant® StripScan app.[6]

A. pH measurement of orange juice samples

Amongst others, pH measurement is relevant in the food and beverage industry, for instance in quality monitoring of fruit juices. Juices are prone to spoilage due to their possible contact with air and microorganisms in the environment during handling. This is a concern because spoiled fruit juice products can lead to various foodborne illnesses. Despite this risk, microorganisms are not usually present in significant amounts because the low pH of these products is not conducive to their growth. Therefore, monitoring the pH of juice products is critical for both their shelf life and safety.

Four orange juice samples were analyzed using the MQuant® pH-indicator strips (pH 0-14), the MQuant® StripScan app, and the corresponding reference card. The pH measurements were compared with the measurements using a pH meter. The results are shown in **Table 1**.

Table 1. Comparison of pH values obtained by MQuant® StripScan and a pH meter

Orange juice sample number	pH	
	MQuant® StripScan	pH meter
1	4	3.95
2	4	3.85
3	4	3.83
4	4	3.87

The results in **Table 1** are averages of five measurements. The MQuant® StripScan app yields results in increments of 0.5 pH units, while the pH meter provides an accuracy of two decimal places. The experimental data indicates that results obtained by the app correspond with the values measured with the pH meter, showing that MQuant® test strips along with the StripScan app are an adequate alternative to measure pH, if the accuracy provided by the app is sufficient for the use case.

B. Nitrate in mineral water

Monitoring of nitrate is important because of its potentially adverse health effects when consumed in excess. An example is the preparation of infant formula, prepared usually with mineral water. In a hypothetical scenario, where a formula is made from water containing 50 mg of nitrate per liter (50 mg/L), that would average about 8.3–8.5 mg of nitrate per kilogram of body weight per day, which is more than double the current acceptable daily intake (ADI) of 3.7 mg/kg bw/day set forth by the EFSA. Water with high nitrate levels used in making infant formula has a serious impact on the daily exposure levels among the formula-fed infants.

Two mineral water samples were measured for their nitrate content. The rapid MQuant® StripScan method was compared to measurements using reflectometry with the Reflectoquant® system, and photometric measurements with the Spectroquant® system. The results are shown in **Table 2**.

Table 2: Nitrate concentration of mineral water samples measured using MQuant® StripScan app, Reflectoquant® system and Spectroquant® measurements

Sample	$NO3^-$ concentration [mg/L]		
	*MQuant® StripScan	*Reflectoquant®	Spectroquant®
Water 1	0	<3	2.7
Water 2	10	12	12.0
Citrus flavored water	10	10	>25.0

*MQuant® StripScan app and Reflectoquant® instrument results are based on the average of 5 measurements

As expected, the photometric approach provided the most accurate results out of the three methods that were compared in this experiment.

As the nitrate content in water sample 1 was very low, it was below the detection limit of the reflectometric and app readers. Accordingly, the Reflectoquant® system correctly determined $NO3^-$ content to be below the detection range of 3 mg/L. The MQuant® StripScan method also correctly determined the concentration to be below the detection limit of 5 mg/L.

The nitrate content of water sample 2 was concurrently determined by reflectometry and photometry to be 12 mg/L. The MQuant® StripScan app determination of 10 mg/L was also in accordance with these reference values, as the incremental values determined by the app are 0 - 5 - 10 - 15 - 20 - 25 - 35 - 50 - 75 - 100 - 250 - 500 mg/L. Thus, the increment value determined by the app is the closest match with the results of the other two methods.

The nitrate concentration of citrus flavored water was also measured. In this case, the Spectroquant® photometric measurements did not give an accurate result because the high sugar content of the sample interfered with the measurement. The results obtained by reflectometry and the MQuant® StripScan app correspond with each other, suggesting that similar method precision is observed here.

To summarize, the measurements obtained with the MQuant® test strips and StripScan app were in range with the reference methods. The accuracy of measurements made was lower due to the system's semiquantitative nature. For accurate values at very low concentrations, the photometric method is best suited. At the same time, the MQuant® test strips and StripScan app are well-suited as a rapid alternative if only binary answers are required (i.e. whether a concentration is above or below a threshold) and to determine the general concentration range of nitrate content in a sample.

Test strip-based methods show advantages with samples containing additives that may interfere with photometric measurements. Here, measurements with test strips yielded adequate results in direct measurements of the sample without the necessity of sample preparation.

Conclusion

The pH of orange juice samples and nitrate concentration of mineral water samples were measured using the MQuant® StripScan mobile app and MQuant® test strips. In all samples, the data obtained with the MQuant® StripScan mobile app was in range in comparison with the results obtained by the reference methods. This allows for the conclusion that this smartphone-based analytical tool presents a viable alternative to more sophisticated, instrument-based methods, such as pH meters for measuring pH, and spectrophotometers for nitrate measurement.

A general advantage of using test strips over pH electrodes or wet chemical methods is their ease of use, speed, low cost as well as the fact that the strips can be discarded with regular waste after use. This can streamline measurement processes drastically, as no cleaning of equipment and disposal of hazardous liquid waste is necessary, saving time and money.

By combining test strips with the readout by the MQuant® StripScan mobile app, accuracy and reproducibility of the test strip readout are improved without the need to purchase a dedicated readout instrument. As an added value, digital data acquisition and traceability are provided by the app solution, together with an easy way to graph, share, and export data for better documentation. This makes this method suitable for on-site and in-process testing, which does not require highly accurate results, and for routine use in laboratories or production sites where pH and chemical screenings are routinely executed.

Acknowledgements

The experimental data for this article was provided by Advanced Analytical R&D, and the creation and revision of this article was supported by Sai Sandeep Mannimala and Maricar Dube.

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It is with these restraints and challenges that we seek to develop and apply new ways of conducting analytical chemistry. By adopting solutions for the digital transformation of the laboratory, we can create more efficient and reliable methods. So how can that be done without painful investments? One simple way is to use the now ubiquitously available smartphones and tablets as portable and affordable chemical analytical devices. They allow a paper-free and seamlessly connected documentation workflow. An example for smartphone-based chemical analysis is the MQuant® StripScan app for the readout of test strips. It allows a reliable mobile on-site result acquisition and documentation of in-process chemical analyses.

The potential of this app was recently recognized by the University of St. Gallen in Switzerland, who awarded the Mobile Business Award 2020 to Merck KGaA, Darmstadt, Germany and their software development partner, Incloud Engineering GmbH. The prestigious award praises the data-based added value of the app, its many possible uses, e.g. in the environmental sector and the food and water analysis, as well as its potential for new user benefits and services.

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We are still at the beginning of leveraging the power of smartphones for our laboratory analyses. The inclusion of this already-available processing power in our laboratory workstreams has the potential to provide unprecedented simple and affordable access to instrumental analysis, by combining the safety and affordability of test strips with the advantages of instrumental readout.

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