SHIMADZU
Excellence in Science

150 YEARS ANNIVERSARY

secrets of science
magazine

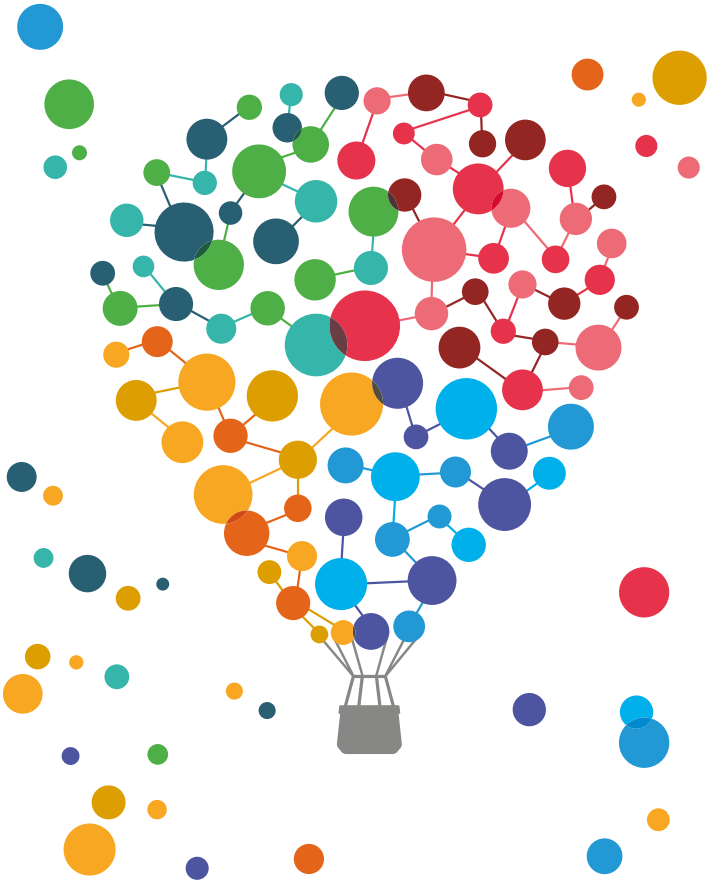
01/2025

Exploring the history and chemistry of G & T
Quantification of quinine in tonic water by UHPLC analysis

Turning visions into reality – since 1875
Shimadzu celebrates its 150th anniversary

No cloudy outlook for acrylic glass
Easy to determine haze value
thanks to LabSolutions UV-Vis

150 YEARS ANNIVERSARY



The five categories in the Secrets of Science

SWITCH ON
Discover more about our products and applications as well as current topics of interest.

MOVE ON
Explore the frontiers of science: new applications and fields of use for our systems and new configurations for applications.

ON SHOW
Accompany Shimadzu in action, with reports on events, exhibitions and seminars.

VOICES
Hear what our customers have to say about their work in interviews and guest-written articles and commentaries.

HANDS-ON
Learn more about tips and tricks for getting the most out of our devices (functions, maintenance, etc.) as well as service topics.

Taste the difference you can make.
Put your science skills to work where they matter.

www.shimadzu.eu/career

Newsletter
Latest news from Shimadzu straight to your inbox with Shimadzu Europe updates.

Subscribe now!

Not a gray area: Meeting the challenge of sustainable hydrogen generation

UK-based start-up aiming to produce carbon-negative hydrogen

Still sealed?

How non-destructive testing can guarantee quality in cosmetic containers

Precision beats estimation – GFR measurement by iohexol plasma clearance

A ready-to-use solution for kidney function measurement

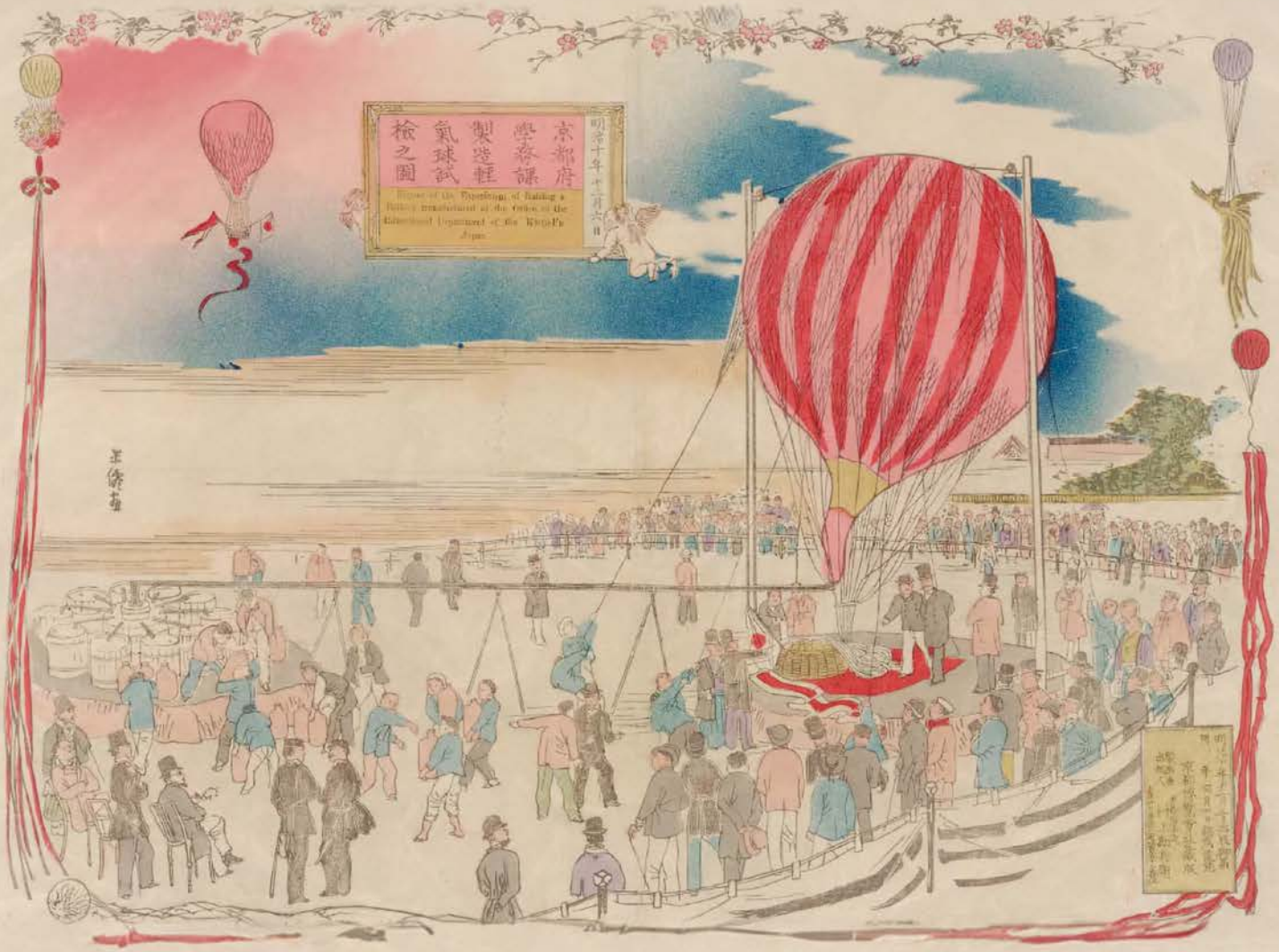
Uncovering the hidden potential

Researching pesticides, a lab stumbled on something interesting about supercritical fluid chromatography (SFC)

A contribution to climate protection

Analytical process control in bioethanol production

Events



Turning visions into reality – since 1875

Shimadzu celebrates its 150th anniversary

Milestones

1875

Genzo Shimadzu Sr. founds the Shimadzu Corporation at the age of 36

In 1875, Genzo Shimadzu (1839–1894) started manufacturing laboratory apparatus for teaching chemistry and physics in schools. Today, his devices are among the oldest exhibits in the "Shimadzu Foundation Memorial Museum", which is located in Kyoto, where the Shimadzu Corporation was founded. Fine examples of the founder's legacy, which is still "alive" and held in honor! The history of the Shimadzu company is a story of continuity – not entirely unlike a trip up in a balloon ...

The date is 6 December 1877. We're in the eleventh year of the reign of the Japanese emperor, posthumously known as Meiji, who shaped an entire era. Almost 50,000 people flock to the imperial park in Kyoto – expectant, hopeful, excited. They want to attend an event that the whole city, no, wait, the whole country – has been talking about for weeks: A 38-year-old blacksmith with a penchant for physics and chemistry wants to launch Japan's first manned balloon flight. Genzo Shimadzu is his name – and the plan is actually a success! The balloon he constructed rises 36 meters into the air together with its crew. His celebrated heroic deed brings him nationwide fame.

The Kyoto Prefectural Government commissioned Genzo Shimadzu to build the balloon because it wanted to promote public interest in the natural sciences. Besides, the importance of Kyoto had also declined after having lost its capital city status to Tokyo in 1868, and the city now focused on promoting industry and science. The balloon flight restored Kyoto's self-confidence and that of its people. ⟶

150 YEARS ANNIVERSARY

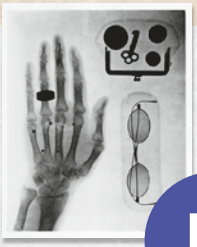
Milestones

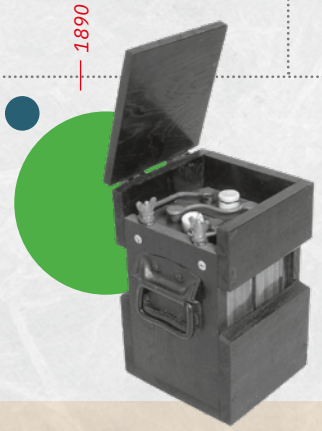
1877
First manned balloon flight in Japan – with a hydrogen balloon built by Genzo Shimadzu Sr.

1880

1890

1896
Genzo Shimadzu Jr. is the first Japanese person to take X-ray images





1897
Construction of a lead-acid battery, which was installed in Japan's first electric car at that time

1900

1909
Japan's first medical X-ray machine

1910

1918
Production of analytical balances begins

1920

A long, successful "flight"

Genzo Shimadzu always endeavored to teach his compatriots (not only schoolchildren but also adults) the "secrets of science" so that Japan could catch up with countries in the West. The company he founded quickly took off on a highly successful trajectory that continues to this day. While the flight route was initially limited to Japan, Shimadzu has been one of the world's most renowned manufacturers of analyzers since the 20th century. Over the decades, new landscapes have opened up, including new industries and new discoveries.

In the 150 years of its existence, Shimadzu has consistently followed hard after its visions and turned them into reality. The company's motto "Excellence in Science" could have come from Genzo Shimadzu himself! But, in fact, it has only been in use since 2012. "Excellence in Science" symbolizes outstanding quality, both in terms of technology and in every single aspect of how it collaborates with customers.

Numerous innovations and world novelties from Shimadzu, which later became industry standards, underline the claim to excellence.

Shimadzu has always been centered around science, and innovation has been the driving force behind the company since 1875. On top of this is the service concept: Shimadzu's first product catalog, which listed all the physics and chemistry devices available at the time, already included the statement that "whatever the customer wants" could be produced. The catalog dates back to 1882.

After Genzo Shimadzu died in 1894 at the age of 55, his eldest son stepped into the pilot's seat: Umeijiro, who called himself Genzo from 1896. Just like his father, Genzo Shimadzu Jr. (1869–1951) was an ingenious inventor.

▲ The company building in Kyoto in the year 1895

▼ Shimadzu's first product catalog from 1882 listed around 110 available instruments

1925
Start of the mannequin production

1930

1940

1952
Japan's first photoelectric spectrometer

1950

1957
Shimadzu's first dual-beam infrared spectro-photometer (AR-275)

1960

1961
The world's first remote-controlled fluoroscopy system – reducing doctors' exposure to X-rays

1956
The first gas chromatograph from Japan (GC-1A)

▲ Umeijiro Shimadzu was born in 1869. He later called himself Genzo – after his father.

At the age of just 15, he built Japan's first electric induction motor, and twelve years later (1896) he and Professor Hanichi Muraoka took the first X-ray images in Japan with a device they had developed – eleven months after X-rays were discovered in Germany. Muraoka knew that he would only be successful with the advanced power generators from Shimadzu.

"The Japanese Edison"

For Genzo Jr., the fact that the machines and other technical equipment used in his home country had until then almost always come from abroad was a great motivation. "The Japanese Edison" registered 178 patents in his lifetime. At the beginning of the 20th century, he developed electricity storage systems, laying the foundations for the company's battery division, which was later outsourced. At this point, Shimadzu became one of the companies that carried progress from Japan to the world, and today the Japanese corporate culture is a guarantee of quality at all locations. The reward for Genzo Shimadzu Jr. included being named one of Japan's ten greatest inventors. The Japanese emperor invited him, along with the other prizewinners, to a dinner in 1930.

Both Genzo Shimadzu Sr. and Jr. pursued the philosophy of "Contributing to society through science and technology" back in the 19th century, and the company has remained true to it to this day. Shimadzu was never just about pure theory but more about the practical application. After all, as the younger Genzo said: "Science is a practical endeavor. There is no point in theoretical knowledge if it isn't applied to help people." Nowhere is this social benefit more evident than in the medical industry – an area in which Shimadzu has been active since the days of Genzo Shimadzu Jr. ⟶

Milestones

1970
The first gas chromatography mass spectrometers launched by Shimadzu

1984
Shimadzu is the first company to develop a technology for the production of holographic gratings (Blazed Holographic Gratings, BHG)

1980 1990 2000

1972
The first TOC analyzers from Shimadzu for monitoring water quality (TOC = Total Organic Carbon)

1978
A modular liquid chromatography system is developed

1999
The world's fastest DNA sequencer is developed

Curiosity, optimism and courage

All of today's employees are committed to the pioneering spirit of the Shimadzu duo. Curiosity was and is the driving force that makes it possible to fly high! Already Genzo Shimadzu Sr. accepted all kinds of orders, even if he had no experience in a particular area. His balloon flight is one example of this. He was characterized by boundless optimism, which still sets the Shimadzu team apart today. Genzo Shimadzu's balloon flight also required courage – another important quality for today's employees.

The company was already broadly positioned in its early days – like in 2025: At that time, Buddhist altars were also built on a regular basis along with equipment for school lessons and special projects. Secured in this way, the winds are almost always favorable!

At Shimadzu, the focus is always on users in laboratories, hospitals and production: With its products, Shimadzu facilitates their work so that they can be pioneers in their respective industries and make all our lives easier and safer. Shimadzu has a good overview (a view from above) of the industries that the company serves and the needs of its customers – and, in this way, can always react appropriately, for the benefit of the company and its customers.

The journey isn't over yet

Never mind the founder, these days it's possible for a Shimadzu employee to achieve world fame: The 2002 Nobel Prize in Chemistry was awarded to Koichi Tanaka from Shimadzu, among others, for his achievements in the field of mass spectrometry. He later developed a system for Alzheimer's research. The two Genzos would be proud of him – and not just him but also the more than 14,000 employees who today contribute to Shimadzu's great success and therefore to scientific breakthroughs. They all make a contribution to society through science and technology and ensure that the exciting journey continues.

▲ In 1953, a Shimadzu X-ray system provided insights into the head of a damaged statue from the Yakushiji temple in the city of Nara

And what's next? Look forward to further milestones in the next issue!

Note
For more information and references, please refer to the digital version of this edition.

◀ Great honor for Genzo Shimadzu jr. (2nd from left): In 1930, he was honored as one of the ten greatest Japanese inventors

◀ It is hardly known that Shimadzu produced mannequins between the 1920s and the 1940s. At times, the company covered 85 percent of the market in Japan.

Waiting for the present

A better test of lithium-ion battery aging waited nearly a decade before anyone asked for it

Waldemar Weber,
Shimadzu Europa GmbH

Ever had a good idea that no one else seemed to care about? Sure, we all have. People are busy, and even the best answer in the world may pass us by if the question it answers isn't one we are currently asking. Some people actually have jobs where they are supposed to go searching for answers to questions no one else is asking. People such as scientists, and scientists such as Waldemar Weber.

Weber is an expert researcher in gas chromatography/mass spectrometry (GC-MS) at Shimadzu Europa. He spends his time exploring new laboratory applications for the powerful, versatile analytical tool that GC-MS provides. He also has a keen interest in battery technology, and one day he became curious about whether he could use GC-MS to better test rechargeable lithium-ion batteries for aging – meaning how long they would last.

As scientists do, he tinkered with his idea and rigorously tested it out in his lab over two years and, finally, wrote it all up and published it. The method worked amazingly well, and surely industry would now leap up and begin using it to improve their products and their bottom lines. There was only one problem: It was 2015. No one cared.

to catch up to the future

What a difference a decade makes

Flash forward to 2024: Since 2015, the market for batteries – and rechargeable lithium-ion batteries (LIBs) in particular – has skyrocketed, creating a self-reinforcing cycle of innovation, lower prices, greater capacity, higher safety and better performance. Much of the impetus behind this has been the dramatically growing interest in sustainability.

The rapidly expanding global market for electric vehicles (EVs) is a perfect example: EVs not only bypass the harmful tailpipe emissions of internal-combustion engines but also allow for the use of sustainably produced energy to power them. And at the heart of any EV – as well as everything from laptops and smartphones to e-bikes, digital cameras and portable power drills – is the rechargeable battery.

Strengthening the weakest link

As important as they are, batteries are sometimes referred to as the weakest link in the electronics at the heart of the modern world. Battery science attempts to design better batteries, for instance ones which degrade less slowly and last longer. So, testing batteries is therefore of central importance to any industry that relies on them in its products or processes. One of the key purposes of testing: How long will this battery last? →

Batteries are more complicated than you might think

Better ways to test battery aging would result in greater predictability of how long a battery could be expected to last as well as point toward ways in which an individual type of battery might be made to perform more efficiently and effectively for a longer period of time. So, the stakes are high! And, given both the complexity of the challenge and the importance of answer, researchers have been hard at work looking for answers. Batteries are complicated. But, for scientists like Waldemar Weber, that's half the fun!

Waldemar Weber began by thinking about the electrolyte solution, which is a crucial part of a typical lithium-ion battery. Decomposition is a continuous chemical process, and the formation of phosphorous-based and other organic products starts already at the production stage of the electrolyte. Thus, the increasing amount of some of the decomposition products is a clear indicator of the progressive aging of the battery/electrolyte.

Could GC-MS simplify the analysis of electrochemical aging?

Weber was curious to know whether GC-MS was suitable for investigating the aging of LIBs using phosphate-based degradation products – specifically trialkyl phosphates. He reasoned that these compounds could be used as markers for electrochemical battery aging because of their slow formation and limited dependence on only a few external parameters.

Using samples provided by the MEET Battery Research Center at the University of Münster (Germany), electrolytes from commercially available 18650 LIBs were investigated. One of the batteries was new, while the other was charged/discharged at 40 °C. After that, both batteries were opened, and the jelly roll was extracted using supercritical fluid extraction (SFE) and acetonitrile as cosolvents. Before the injection of 1 µL, the extract was dissolved with dichloromethane (DCM) 1:10.

To analyze the phosphate species, Weber used the scan mode on a Nexis GC-2030 with a GCMS-QP2020 NX (gas chromatograph plus mass spectrometer detector). This enabled the identification of the different analytes based on their spectra.

The corresponding retention times used *m/z* traces, the detected areas of the different compounds being summarized in Table 1. The fluorinated species could be found in both the new and the aged battery. The content of ethyl methyl fluorophosphate (EMFP) and diethyl fluorophosphate (DEFP) in the aged battery is significantly higher than in the new one.

In contrast to the fluorinated compounds, the tri-alkylated phosphates are formed significantly slower and are usually not detectable in a fresh electrolyte, offering the possibility of using their formation as an indicator of battery aging.

The GC-MS chromatograms thus obtained and the corresponding MS spectra are shown in Figure 1. As indicated in Figure 2, trimethyl phosphate (TMP), ethyl dimethyl phosphate (EDMP) and diethyl methyl phosphate (DEMP) could be detected in the electrolyte after 1,500 charge cycles.

An idea whose time has come

In 2015, Weber was successful in proving that gas chromatography/mass spectrometry using scan measurements of phosphate-based degradation products offers a simple and effective new method for the quality control of battery aging. Companies and research institutions wishing to apply this method to their own needs are encouraged to do so.

Better battery testing is good for business, consumers and the planet

On the frontiers of science, working together is the best way to not only survive but to prosper. Being able to better test how and how much a battery ages will be of immense value in ensuring that battery technology continues to evolve and spread its benefits. And – in whatever field we may find ourselves – it's important to remember that patience pays off and that a good idea is never wasted. Better ways of doing things eventually win out over traditional ways. Even if there are occasional delays.

Note

For more information and references, please refer to the digital version of this edition.

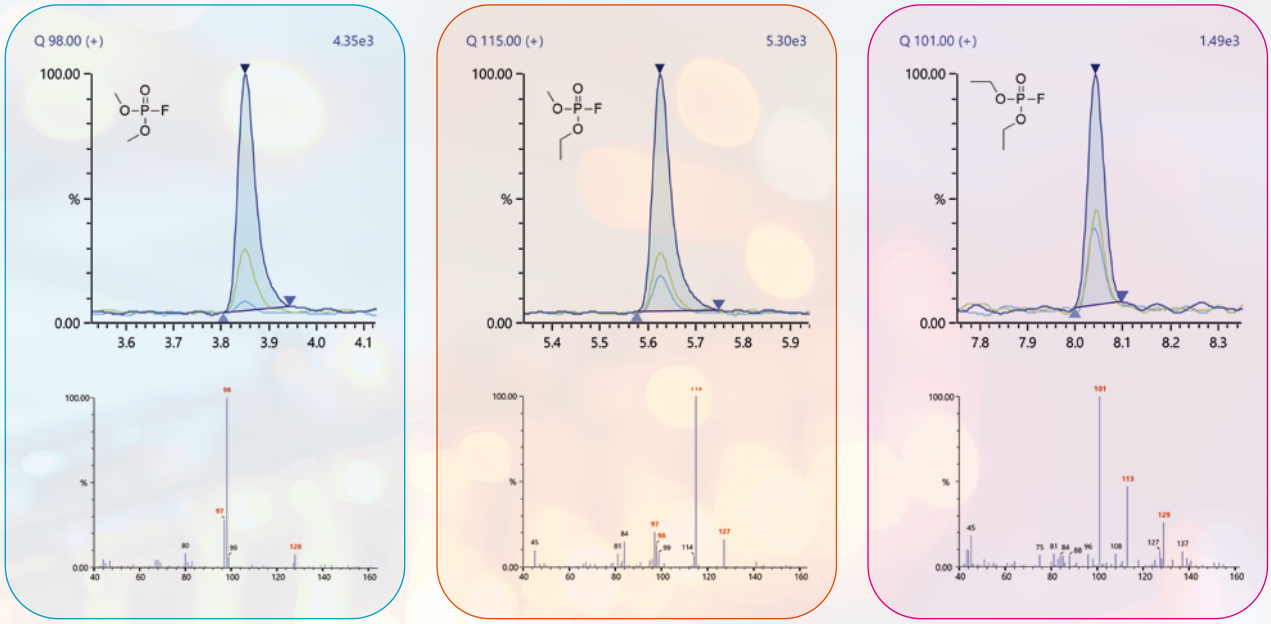


Figure 1: Mass spectra of the detected fluorophosphates in the aged LIB: DMFP (left), EMFP (middle), DEFP (right)

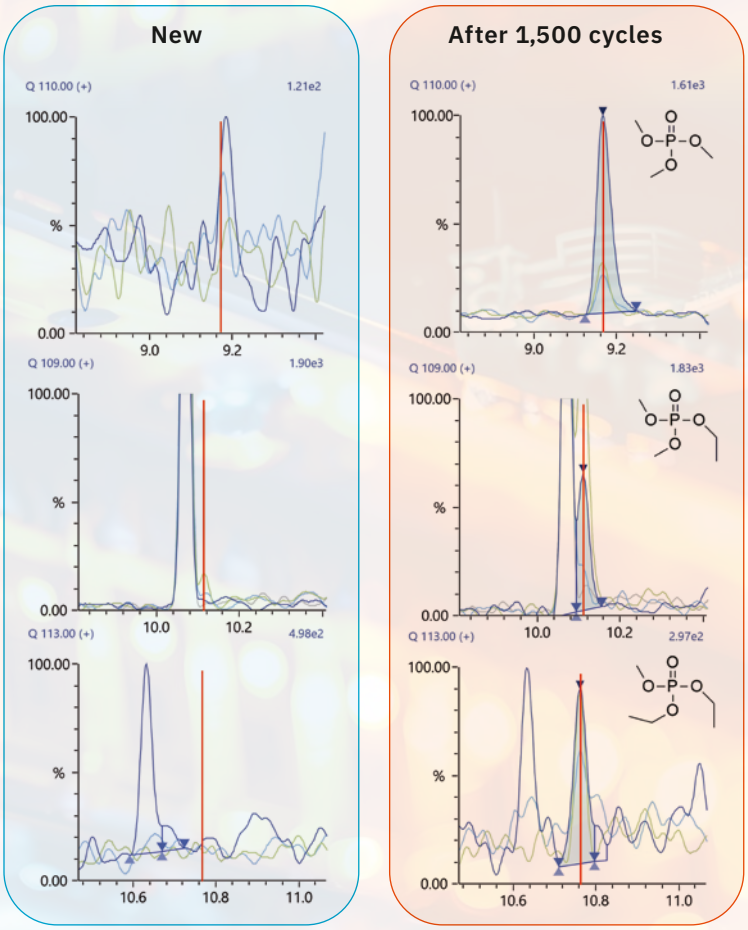


Figure 2: GC-MS chromatogram of the TMP, EDMP and DEMP in a new LIB (left) and after 1,500 cycles (right)

Compound	Chemical structure	*m/z* for SIM	Ret. time [min]	Peak area	
				New battery	After 1,500 cycles at 45 °C
Dimethyl fluorophosphate (DMFP)		97, 98, 128	3.83	15,304	11,406
Ethyl methyl fluorophosphate (EMPF)		97, 115, 127, 141	5.64	7,015	14,619
Diethyl fluorophosphate (DEPF)		101, 113, 129	8.05	2,136	3,426
Trimethyl phosphate (TMP)		140, 110, 109, 95	9.12	N.D	3,952
Ethyl dimethyl phosphate (EDMP)		153, 139, 127, 110, 109, 96, 95	10.11	N.D	1,028
Diethyl methyl phosphate (DEMP)		141, 113	10.77	N.D	588
Triethyl phosphate (TEP)		155, 127, 109, 99	N.D	N.D	N.D

Table 1: The differences between the peak areas of seven compounds in a new LIB and an aged one

Not a gray area: Meeting the challenge of sustainable hydrogen generation

UK-based start-up aiming to produce carbon-negative hydrogen

Dr. Michael Sims,
Wild Hydrogen

Figure 1: Hydrogen offers the prospect of greening-up heavy transport and industry processes that are otherwise difficult to decarbonize – but only if the method of generating hydrogen itself doesn't release CO_2

The potential of hydrogen as an environmentally benign fuel is only to be realized if it can be turned cost-effective and if society is able to move away from the current market dominance of "gray hydrogen" and its unsustainable CO_2 emissions. Pyrolysis of biomass has been well studied as a potentially carbon-neutral way of making hydrogen, but it's tended to require extensive feedstock processing and high energy use. Now, however, the UK-based start-up Wild Hydrogen thinks they've overcome all these problems with a new design of gasification reactor. We talk to them about how they plan to make hydrogen generation carbon-negative and how they're using Shimadzu's GC-MS to understand the composition of their gaseous, liquid and solid products.

Gray, blue, green … and clear

But there's a big problem with hydrogen – and that's the way it's generated. The market is currently dominated by **gray hydrogen**, which is made by gasifying fossil fuels but emits lots of CO_2 in the process. **Blue hydrogen**, generated the same way but with carbon capture and storage, is resource-intensive and thus very expensive. And **green hydrogen**, produced by electrolysis of water with electricity from renewable sources, has the same problems and uses scarce materials too, making it uneconomic.

So, how can we make hydrogen production both less resource-intensive while at the same time eliminating – or even reversing – the CO_2 emissions that typically accompany it? The R&D company Wild Hydrogen thinks it has the answer, and they're using a Shimadzu GC-MS to help them on their journey to what they call **"Clear Hydrogen"**. ⟶

Adding carbon capture to biomass gasification

That idea centers on the gasification of biomass into hydrogen and CO_2, using a reactor-based process that effectively has the capabilities to remove atmospheric CO_2 by capturing it from the produced gas stream. Because the feedstock is not derived from fossil carbon and because the CO_2 can be captured, this method is potentially not just carbon-neutral but carbon-negative. So, at a stroke, it would generate the hydrogen needed for tomorrow's economy while also (in effect) using photosynthesis to do the difficult work of removing CO_2 from the atmosphere, which is driving climate change.

They've made three major advances that have enabled them to make the production of hydrogen economically viable:

- **Minimal pre-preparation:** Their method does not require extensive processing of the feedstock prior to introduction into the reactor.
- **Reduced heating costs:** By careful reactor setup and workflow, they've been able to reduce the amount of time and energy needed to raise the biomass to the temperature and pressure needed for gasification.
- **Minimal use of resources:** By using only readily available metals and ceramics, their approach eliminates the need for scarce or hazardous rare earth metals. Unlike some other methods, large amounts of water are also unnecessary.

To demonstrate that their concept works in practice, the team at Wild Hydrogen has been busy developing a series of prototypes over the last two years, which have steadily increased in scale, efficiency and robustness. Their reactor design has also been shown to work with a variety of different biomass feedstocks, including bio-energy crops, forestry residues, macro-algae as well as waste products such as oversized compost. The reactor even gives good results with waste plastic!

Figure 2: Straw, wood pellets and compost – just three of the biogenic material feedstocks that the team at Wild Hydrogen have been investigating for hydrogen generation

Assessing hydrogen purity … and by-product composition

The result of Wild Hydrogen's biomass conversion process is a gas that is rich in hydrogen, but which also contains carbon dioxide, carbon monoxide, methane and a range of other volatile compounds at low concentrations. However, to make their reactor a viable commercial proposition, they need to produce gas that is high in purity and have an analytical system that can provide evidence of that purity.

The purity of their hydrogen, important as it is to the company, isn't the end of the story. The gasification process also results in solid biochar and a small amount of liquid bio-oil (or tar). Understanding the chemicals present in these products is essential for working out the processes that are happening inside the reactor and thus optimizing the yield of hydrogen. But the team also has an eye on keeping the whole process as "circular" as possible by reusing these by-products: The biochar could be used for CO_2 capture, for example, while the bio-oil could be added back into the feedstock to generate more hydrogen.

Figure 3: Gas analysis at Wild Hydrogen involves taking an aliquot from the gas bags used for sample collection – which is necessary because the conditions in the biomass reactor preclude online sampling

Understanding the composition of all these gases, liquids and solids needs a versatile analytical setup – and that's where Shimadzu comes into the story.

Developing a bespoke analytical system

The conversation with Shimadzu started early on, following a meeting at a laboratory tradeshow event. The team at Wild Hydrogen was particularly excited by the possibility of covering the whole range of gaseous analytes in one run, and the decision to go with Shimadzu was cemented after realizing the value of Shimadzu's consultative approach and once they'd seen firsthand the capabilities of their instrumentation.

Soon it was clear that a custom system was going to be needed, because the conditions within the reactor precluded using online sampling, while Wild Hydrogen's desire to accommodate analyses of non-target compounds in liquid and solid fractions as well as gas samples meant that MS detection (rather than FID, TCD or BID) would be required.

Off-the-shelf systems for this kind of work aren't readily available, but Shimadzu specializes in modifying standard GC-MS instruments for specific applications, so they set to work on devising a setup for Wild Hydrogen. The result was a bespoke system based on the Shimadzu GCMS-QP2020 NX, with the setup for gas analysis involving two sample loops filled from a canister or gas bag. The loops are connected to PLOT columns that provide excellent performance for hydrogen, carbon dioxide and the other permanent gases expected. ⟶

Figure 4: Wild Hydrogen staff member Dr. Michael Sims, pictured with the custom Shimadzu system that Wild Hydrogen are using to check the composition of the gases, liquids and solids generated by their biogenic material gasification process

Research Chemist Dr. Michael Sims

The system was installed in summer 2023, at roughly the same time that Dr. Michael Sims joined Wild Hydrogen as a Research Chemist. In his current role, he's working on their fourth reactor prototype, nicknamed "Mini", with a focus on maximizing energy efficiency and recovering heat.

Versatile instrumentation and responsive staff

Having been using the Shimadzu system for nearly a year, Michael says he's very happy with it: *"What we like about it is its versatility – we can adapt the setup to run a number of different analyses, and it's very simple to switch between them. If we'd just got a gas analyzer or an off-the-shelf GC-MS system, we wouldn't have that ability."*

And having an in-house system means he can respond quickly to internal requests, because they don't need to rely on expensive and time-consuming outsourced analyses. *"With our Shimadzu system, I can run a gas analysis, and within 10 minutes I can tell the rest of the team what the composition is."*

The level of service they've received from Shimadzu has been important to Michael and the rest of the team at Wild Hydrogen, he adds: *"Getting the system up and running was seamless, and the aftercare has been very positive too – everyone's really approachable, and if we have a question, however small, we can just get in touch."*

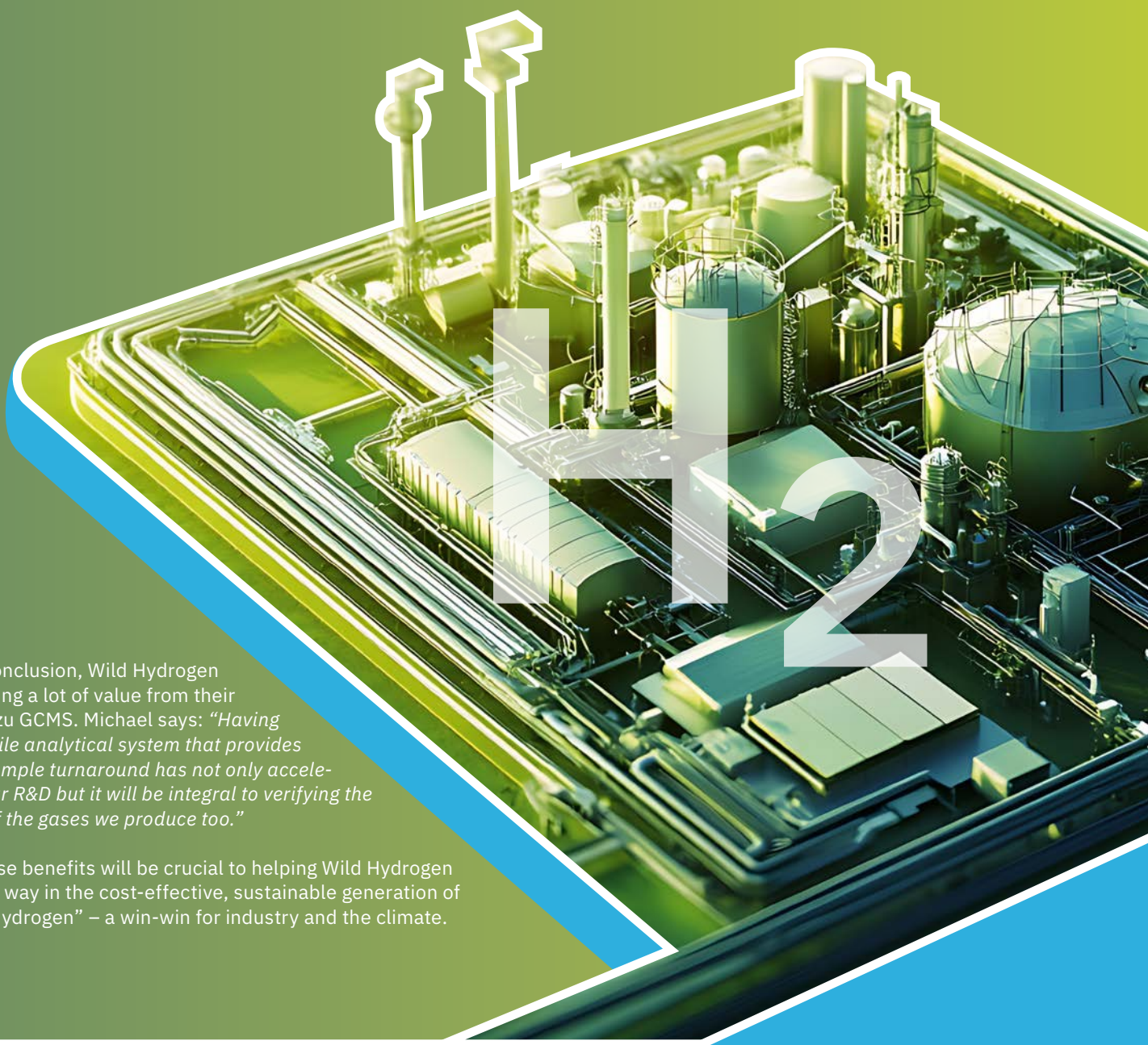
Figure 5: Dr. Michael Sims inspects the column oven of the custom Shimadzu GCMS, showing in the foreground the guard column and two of the compound separation columns (yellow and orange). The use of multiple columns means that the total flow of gas to the MS is higher than normal – but this is easily handled with the system's high-capacity dual-phase turbo pump, capable of tackling up to 15 mL/min without loss of sensitivity.

Leading the way in sustainable hydrogen

Currently, says Michael, they're embarking on projects to investigate the best conditions for cleaning up their gases. The first aspect is downstream technology to separate out the CO_2 from the hydrogen, followed by purification equipment.

For the hydrogen, Michael says a lot will depend on what is requested by the purchasers of their gases. *"But"*, he adds, *"we're basically aiming to generate hydrogen of sufficient purity suitable for the fuel cells used in hydrogen-powered vehicles."*

Note
For more information and references, please refer to the digital version of this edition.



So, in conclusion, Wild Hydrogen are getting a lot of value from their Shimadzu GCMS. Michael says: *"Having a versatile analytical system that provides quick sample turnaround has not only accelerated our R&D but it will be integral to verifying the purity of the gases we produce too."*

And those benefits will be crucial to helping Wild Hydrogen lead the way in the cost-effective, sustainable generation of "Clear Hydrogen" – a win-win for industry and the climate.

Still sealed?

How non-destructive testing can guarantee quality in cosmetic containers

Sebastian Fürst, Shimadzu Europa GmbH

Consumer safety and product quality are of immense significance for manufacturing companies. Both can be intimately linked, as, for example, with containers for cosmetic products: The quality and safety of cosmetics can only be guaranteed if the containers are completely sealed. A test should demonstrate whether the industrial computer tomograph XSeeker 8000 helps to take a look "behind the scenes". Can CT analysis be used to make valid statements about the quality of the containers – and even the contents themselves?

We've all been there

This has probably happened to everyone who has used cosmetic products: As soon as you open the outer packaging, you see that the actual container has not been sealed completely, allowing the expensive contents to leak, even if only a little, or that other damage has occurred during transport. It's quite frustrating, and not just for you. After all, these days everything can be shared instantly on social media, where it may impact the producer's reputation too. And doesn't a leak also mean that something can get into the high-quality product and impair its quality or, in the worst case, that we're now holding a product that's harmful to health?

"How can manufacturers ensure that we always receive a safe product?" product specialist Kayo Migita from the Shimadzu Corporation wondered. Her answer: *"They have to recognize the containers' weak points without destroying them – then they can take the specific products out of circulation first, if necessary, and manufacture better products in the future."* Is computed tomography the solution? To answer this question, Migita took a closer look at some containers using the XSeeker 8000.

Computed tomography – not just at the doctor's office

Many people are probably familiar with computed tomography (CT) in a medical context. *"The industrial use is still relatively unknown, although the advantages of the technology for industry are certainly obvious,"* says Migita. *"You can take a peek inside the test object without influencing it at all."* How does this work exactly?

Simply put, a computer tomograph consists of the following components:

– X-ray source
– Detector
– Rotary mechanics
– Analyzing computer

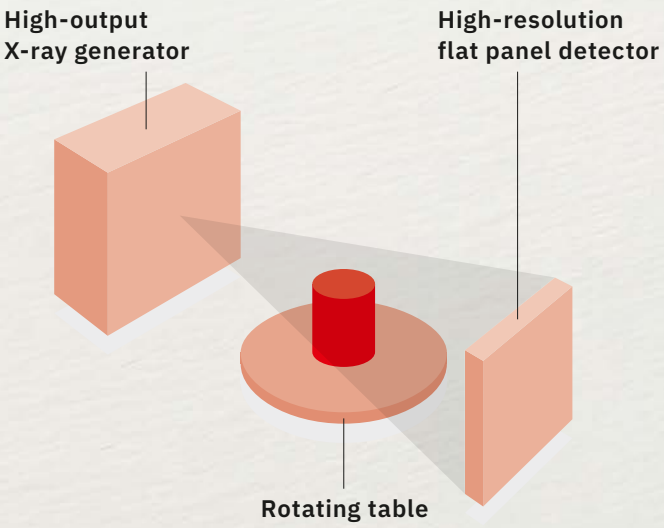


Figure 1: Exemplary illustration of how a computed tomography measurement works

The X-ray source emits X-rays that penetrate the test object and hit the detector in attenuated form. The radiation is attenuated differently, depending on the material and layer thickness. The result is a two-dimensional X-ray image, which is used to examine bone fractures, for example. To create three-dimensional images of the test object, a large number of these images from different perspectives are required. Thus, a rotation between the X-Ray source/detector and the object is needed.

While in medical CT scanners the combination of X-ray source and detector rotates around the patient to generate the different cross-sectional images, in an industrial CT the source-detector combination is fixed, and it's the test object that rotates. By combining the cross-sectional images from the different rotations, a complete three-dimensional model is created in the analyzing computer, which can be examined layer by layer. →

Figure 3: There is less liquid in the center of the make-up than at the edges

Figure 4: The measurement showed a 0.58 mm-wide gap

Figure 2: The samples: cushion foundation (left), liquid lipstick (middle), eye shadow (right)

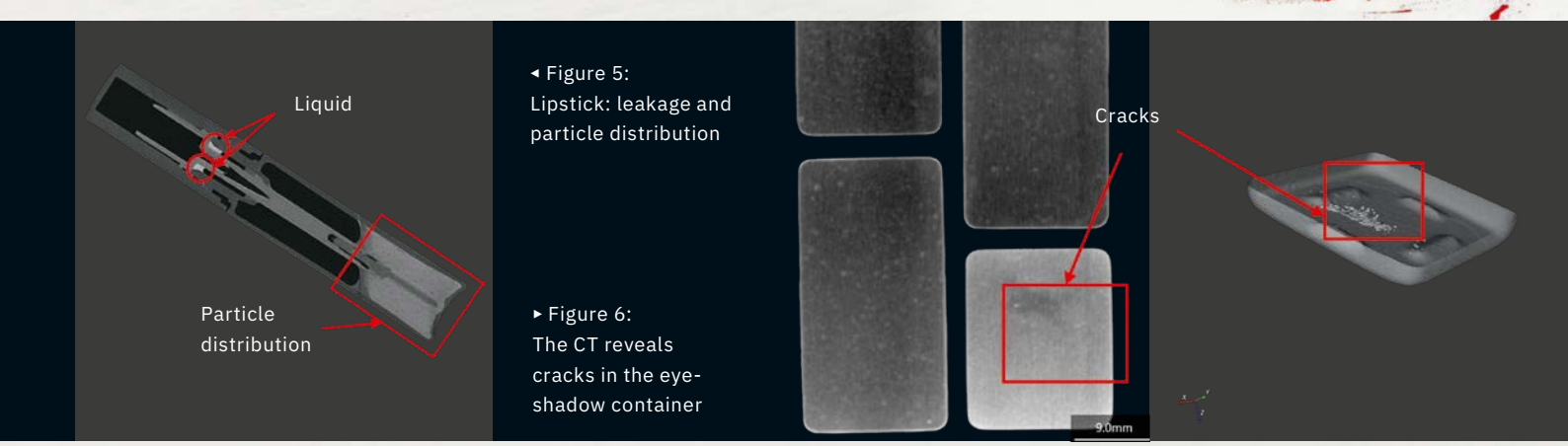
The first glimpse

For this reason, Kayo Migita selected three different cosmetics to analyze with the XSeeker 8000. The XSeeker 8000 is a compactly sized industrial CT scanner, characterized by high X-ray radiation. A 160 kV output rate for a system placed on a table is a special feature! Migita was curious to see what insights she would glean.

"Cushion foundation" (make-up with cushion)

The box for the cushion foundation is certainly one of the more complex containers in the field of cosmetics. It consists of an outer lid, an inner cover and a base for holding the sponge. Depending on their function, the individual components are either glued, screwed or clamped, providing plenty of opportunity for a leak to occur. The Japanese product specialist reports: *"In the open Xseeker 8000, each sample is lit up so that its shadow indicates its position in relation to the detector. This allowed me to quickly position my sample perfectly. After placing it properly, I was able to scan and obtain a clear image of the container. The individual components have been reproduced in great detail. Using the measuring function, I determined a gap thickness of 0.58 mm between the inner fixtures. I found it equally interesting that the image also gave me information about the moisture distribution within the make-up."* There was considerably less liquid in the center of the make-up than on the outside. Was this intended by the manufacturer?

Note
For more information and references, please refer to the digital version of this edition.



◂ Figure 5:
Lipstick: leakage and particle distribution

▸ Figure 6:
The CT reveals cracks in the eye-shadow container

Liquid lipstick

Secondly, the CT expert tested the liquid lipstick. A crack, break or leak could not be detected in the CT image, but a little trick showed that the device can detect leaks in the event of a problem: *"I deliberately put some liquid lipstick on the threaded part of the cap. Now I hoped that the device would show the liquid in a different color due to its higher density compared to the container – and I was right. The liquid I applied appeared as a small white area against a dark background."* And when analyzing the liquid, Migita was also able to identify interesting additional quality features: For example, the image showed that the particles were equally distributed. *"This will certainly allow the cosmetics to be applied evenly,"* Migita commented with a smile.

Powdered eyeshadow

The last sample that Kayo Migita analyzed was powdered eyeshadow. The packaging seals made a good impression, and the sharp images showed the different consistencies and textures of the products in the packaging. Migita shared: *"I could clearly see different particle sizes and also the differences in density based on the gray scale as well as fine cracks in the eyeshadow below the surface that would have stayed hidden during a visual inspection."*

Helping to improve quality

Kayo Migita is very impressed by the possibilities of CT measurement of cosmetics and their containers and is eager to hear what the manufacturers have to say about the results when she forwards them. Not only could we tell if there were any leaks and verify the integrity of the products, but we could also draw conclusions about the quality of the cosmetics, for example about the homogeneity of the particle distribution. Migita's verdict on this everyday test: *"I'm sure that the XSeeker 8000 will improve the quality of the products that reach us users in the end, so that, thanks to them, we are able to start the day in the morning even fitter and fresher."*

Exploring the history and chemistry of G & T

Quantification of quinine in tonic water by UHPLC analysis

Annika Malz, Shimadzu Europa GmbH

This first article of a three-part series on the classic longdrink gin and tonic takes a look at its origin in British history and the right amount of quinine which once served as a malaria antidote.

"Gin and tonic has saved more Englishmen's lives, and minds, than all the doctors in the Empire." This quote by Winston Churchill refers to a time when gin and tonic was not ordered but prescribed. In 1854, on an expedition on the Niger, Scottish physician William Balfour Baikie used quinine from the cinchona tree to successfully prevent malaria, rather than as an aftertreatment. This initial action laid the foundation for the rise and expansion of the British Empire, because it helped push back malaria, which once existed all over Europe, including Britain, as recently as the early 20th century. Quinine was then mixed with gin – among other spirits – and, later on, lemon was added to prevent scurvy. The first known record of the name "gin and tonic" came about in a magazine in 1868 when partygoers called for the cocktail at the end of a horse race in Lucknow, India. Today, quinine is widely used in the food and beverage industry, especially in tonic water, a popular carbonated drink. Given the pharmacological effects and potential side effects of quinine, it is crucial to accurately monitor its concentration in consumer products. High-performance liquid chromatography (HPLC) plays a central role in this monitoring process.

Quinine in tonic water – how much is too much?

HPLC is an analytical method renowned for its high precision, sensitivity and reliability in separating and quantifying components in complex mixtures. This article aims to evaluate the efficiency and accuracy of HPLC in determining quinine levels in various tonic water samples. By optimizing chromatographic conditions, a robust analytical procedure was developed that can be applied in monitoring compliance with legal limits.

The FDA (United States Food and Drug Administration) and the European Union state that the concentration of quinine as a flavoring agent in carbonated beverages must not exceed 83 mg/L and 100 mg/L, respectively, and it has to be declared on the bottle each time it is added. The results of this analysis are of particular interest as they not only ensure the consistency and safety of commercial products but also help to minimize potential health risks for consumers.

Analytical conditions

The method was developed using the LabSolutions MD™ software. Table 1 shows the optimized analytical conditions. →

Sample preparation

For the preparation of standard solutions in the concentration range of 12.5 to 100 mg/L, accurately weighed quantities of a quinine standard substance were dissolved in ultrapure water. The tonic water samples were filtered using a 0.45 µm filter and injected into the HPLC without further dilution.

Method performance

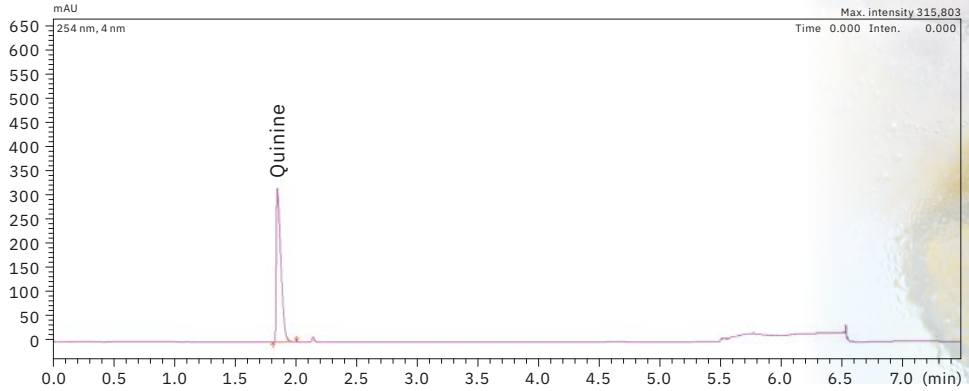
The linearity for the calibration standards prepared in a range of 12.5 to 100 mg/L with the coefficient of determination R2 > 0.9999 was excellent for quinine. Figures 1 and 2 display the chromatogram of the 100 mg/L standard solution and the corresponding calibration curve of all standards, respectively.

Results of the analysis of ten tonic water samples

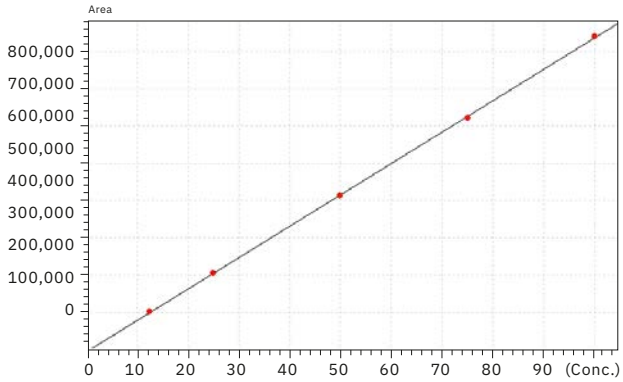
In Table 2, the results of the quinine content of ten different samples of measured tonic water are presented. Remarkable here is that the tonic sample 1 shows a higher content of quinine than allowed according to FDA regulations for beverages. Figure 3 illustrates a chromatogram of a tonic water sample measurement.

Cheers to a good and reliable HPLC method!

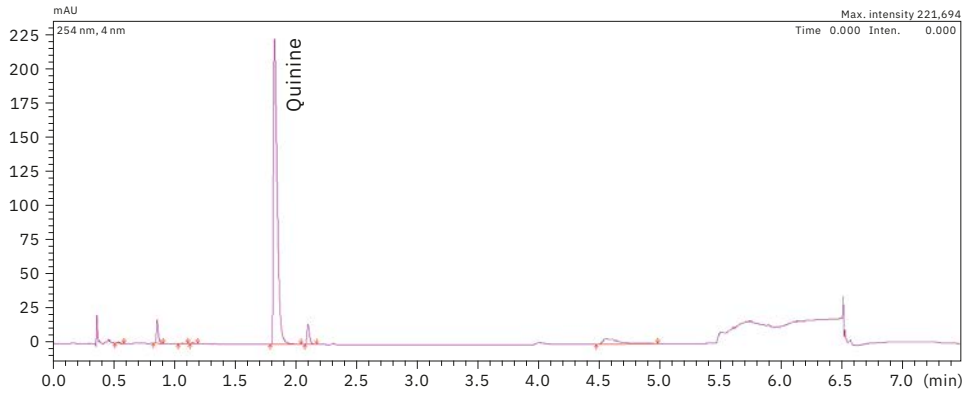
For the determination of quinine in tonic water, the developed HPLC method proved its worth. The quantification in a variety of tonic water samples showed compliance with the regulation in all but one product. To make a valuable statement, there must be more results from different bottles of one vendor, but for the tests just a single bottle of each tonic water was used. Nevertheless, a good overview of the quinine content of different tonic waters could be presented, which also reveals a wide variety of concentrations, probably resulting in a different taste of the beverages.



▲ Figure 1: Chromatogram of a 100 mg/L quinine standard solution



▸ Figure 2: Calibration curve of 12.5 mg/L, 25 mg/L, 50 mg/L, 75 mg/L and 100 mg/L quinine



▾ Figure 3: Chromatogram of a tonic water sample

LC system	Nexera XR UHPLC system
Column	Shim-pack™ Velox C18, 100 mm x 3.0 mm I.D., 2.7 µm
Mode	High pressure gradient
Mobile phase	A) Water 0.1 % formic acid B) Acetonitrile 0.1 % formic acid
Flow rate	1.0 mL/min
Gradient	0 min, 5 %B – 5 min, 40 %B – 5.01 min, 95 %B – 6 min, 95 %B – 6.01 min, 5 %B – 7.50 min, 5 %B
Column temp.	40 °C
Sample volume	2 µL
Detection	SPD-M40A (PDA @ 254 nm)

Table 1: Analytical conditions

Tonic water	Measured conc. [mg/L]
Tonic 1	86.4
Tonic 2	46.3
Tonic 3	75.8
Tonic 4	65.1
Tonic 5	70.6
Tonic 6	33.1
Tonic 7	68.3
Tonic 8	64.9
Tonic 9	56.4
Tonic 10	60.8

▸ Table 2: Measured content of quinine in 10 different tonic waters

Note

For more information and references, please refer to the digital version of this edition.

Coming soon: Organic acids and sugars in G & T

If you have enjoyed this article, you can look forward to part two of the series covering organic acids and sugars in G & T.

Precision beats estimation – GFR measurement by iohexol plasma clearance

A ready-to-use solution for kidney function measurement

Shahriar Kermanshahian, Paul Gentil, Nephrolyx GmbH

The glomerular filtration rate (GFR) plays a vital role in monitoring the kidney function. Even though kidney diseases rank as the 10th leading global cause of death, resulting in 1.3 million deaths annually (2019), the vast majority of GFR determinations are based on estimation (eGFR). These estimations lack clinical accuracy, which can lead to uncertainty in clinical decision-making, especially for critical patient cases. According to the international Kidney Disease: Improving Global Outcomes (KDIGO) organization, reliable and accurate results can only be achieved by direct measurement of the GFR (mGFR) using exogenous markers such as iohexol.

Imagine if your car had no speedometer and you always had to estimate your speed. Or if the length of the jumps in the Olympic Games was estimated instead of precisely measured. Or if soccer referees had a watch but simply guessed when it was time for the final whistle. Sounds absurd? Well, in the vital field of kidney health, people have to actually estimate how badly a diseased kidney is affected or how to determine the right dosage of cancer treatment and stem cell therapy. The problems of this "guessing" dilemma of the glomerular filtration rate (GFR) are described below in detail – and the solution for a far better diagnostic method follows en suite.

The definition of the Glomerular Filtration Rate (GFR) and the dilemma of inaccuracy

Clinical assessment of kidney function is extremely important to the practice of medicine, and the glomerular filtration rate (GFR) is widely accepted as the best index of kidney function. Currently, estimated GFR (eGFR) based on serum creatinine or filtration markers such as cystatin C is widely used by clinical laboratories. However, approximately 10–20 % of estimated kidney function values are deviating by more than 30 % from the measured GFR. The estimated values are highly prone to error in many clinical settings such as patients with extremes of age and body size, severe malnutrition or obesity, diabetes mellitus, cancer, disease of skeletal muscle, paraplegia or quadriplegia and vegetarian diet. In these cases and circumstances such as evaluation for kidney donation or before administration of prolonged courses of nephrotoxic medications e.g., cytostatic agents or antibiotics, decisions based on inaccurate estimates may have harmful consequences.

The solution: Measuring GFR using exogenous markers

Measuring GFR (mGFR) using plasma clearance of the exogenous marker iohexol is recognized as the gold standard by the latest KDIGO 2024 CKD Guideline.
The KDIGO Guideline identifies clinical scenarios where estimated GFR is prone to error and outlines selection criteria for patients requiring GFR measurement (Figure 1). The guideline also recommends that all nephrologists →

Indications for GFR measurement (mGFR)

Domain	Specific clinical condition
Illness other than CKD	Malnutrition Cancer Heart failure Cirrhosis Catabolic, consuming diseases Muscle-wasting disease
Body habitus and changes in muscle mass	Eating disorders Extreme sports/exercise/bodybuilding Above-knee amputation Spinal cord injury with paraplegia/ paraparesis or quadriplegia Obesity (BMI > 40, class III)
Medication effects	Steroids (anabolic, hormonal) Decreases in tubular secretion Broad-spectrum antibiotics that decrease extrarenal elimination
Diet	Low-protein diet Keto diet Vegetarian High-protein diet and creatine supplements
Lifestyle	Smoking

[based on KDIGO CKD 2024: table 8 – page S179]

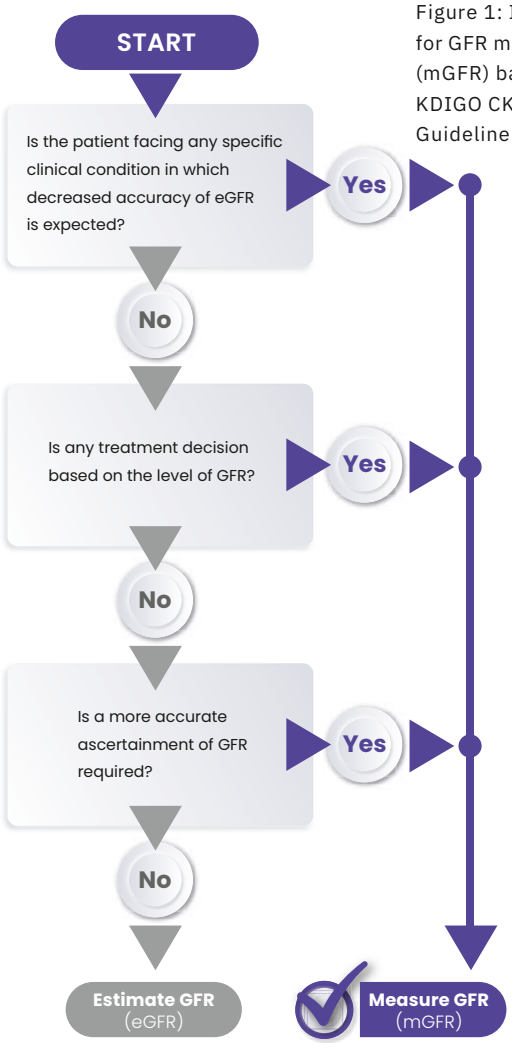


Figure 1: Indications for GFR measurement (mGFR) based on KDIGO CKD 2024 Guideline

should ideally have access to at least one method to measure GFR using exogenous markers. Even though various methods for measuring GFR were available, they often required complex and time-consuming procedures, hence could not be easily performed routinely, until now.

Is there a method to establish easy and routine GFR measurement in laboratories?

In order to answer this crucial demand, Nephrolyx has developed the CE-marked Nephrolyx IVDx kit and an associated software platform for GFR measurement via iohexol plasma clearance (Figure 2). The test is intended for the in-vitro diagnostic use to quantify the serum iohexol concentration, followed by the calculation of the resulting glomerular filtration rate (GFR) as an aid in the diagnosis, monitoring and treatment of kidney diseases. The main steps for the test are illustrated in Figure 3. This article describes the reliable protocol to determine iohexol concentration in human serum using the IVDx kit developed by Nephrolyx in a rapid and highly accurate measurement.

▲ Figure 2: Nephrolyx IVDx test kit for use in (U)HPLC analysis

Sample arrival 1

- Serum tube(s) is/are sent to the lab together with the patient information

Sample preparation 2

- 20 µL of serum + 180 µL of internal standard are mixed and centrifuged prior to the measurement

Sample measurement 3

- Iohexol quantification by (U)HPLC method with UV or DAD detection
- Analytical method operated by (U)HPLC software

Reporting result 4

- Quantitative iohexol results are used to calculate mGFR values by the GFRx Software Module integrated into the DNPx platform
- Reporting the results via LIMS integration is possible

► Figure 3: Main steps to measure GFR using the Nephrolyx IVDx kit and associated GFRx Software Module integrated into the DNPx software platform

Material and methods

Sample preparation

The laboratory received human serum samples, collected after 3, 4 and 5 hours following a 5 mL iohexol injection to patients. To start sample preparation, 20 µL of each calibrant (C1–C6), quality control material (QC1–QC3) and sample were pipetted into the 96-well plate in duplicate. 180 µL of the Nephrolyx internal standard (IS) were added to each well. After 2 minutes of shaking at 1,000 rpm, the 96-well plate was set on the top of the capture plate and centrifuged for 30 minutes at 1,500 G. The filtrated samples were collected into the capture plate and ready to be measured on the (U)HPLC instrument.

UHPLC analysis

In this assay, the analysis was performed on Chromaster-Ultra Rs UHPLC (Hitachi) as reference and Nexera X3 UHPLC (Shimadzu) instruments. The separation of analytes on both systems was achieved via a binary gradient (details in Table 1) and an analytical column of Nephrolyx at +50 °C. The analytes were quantified using a UV-Vis detector.

Results

The results (Table 2) show very good reproducibility between the duplicates and high accuracy compared to the theoretical concentrations for both devices. The calculated values for the standard curves and the intra-/inter-batch deviations are shown in Table 3 and Table 4, respectively. For this assay, 50 samples were used to measure intra- and inter-assay precision. The intra-assay →

◂ Table 1: Binary gradient

Time	Pump settings		
	% A	% B	Flow
0.00 min	100 %	0 %	1.0 mL/min
1.00 min	86 %	14 %	
1.01 min	0 %	100 %	
1.05 min	0 %	100 %	
1.06 min	100 %	0 %	
2.50 min	100 %	0 %	

▾ Table 3: Results for the standard curve measured with Nephrolyx calibrant on ChromasterUltra Rs and Nexera X3

Instrument	Slope	Intercept	R^2
ChromasterUltra Rs (Hitachi)	187.7538	0.2199	0.9996
Nexera X3 (Shimadzu)	187.3024	0.2801	0.9995

Sample name	Theoretical concentration [µg/mL]	Average measured concentration on Chromaster-Ultra Rs [µg/mL]	CV [%] between duplicates (Chromaster-Ultra Rs)	Deviation [%] (Chromaster-Ultra Rs to assigned value)	Average measured concentration on Nexera X3 [µg/mL]	CV [%] between duplicates (Nexera X3)	Deviation [%] (Chromaster-Ultra Rs to assigned value)
C1	500.00	501.48	0.1 %	0.3 %	500.56	1.4 %	0.1 %
C2	222.22	224.12	0.6 %	0.9 %	221.13	0.7 %	–0.5 %
C3	98.77	95.26	2.1 %	–3.6 %	97.00	0.3 %	–1.8 %
C4	43.90	43.67	0.9 %	–0.5 %	44.66	1.1 %	1.7 %
C5	19.51	19.56	1.6 %	0.2 %	19.66	1.1 %	0.8 %
C6	8.67	8.67	3.3 %	0.0 %	8.63	3.9 %	–0.5 %
QS1	333.33	329.03	0.5 %	–1.3 %	333.06	1.2 %	–0.1 %
QS2	65.84	64.64	1.5 %	–1.8 %	67.59	1.7 %	2.7 %
QS3	13.01	13.08	1.7 %	0.5 %	12.85	0.5 %	–1.2 %

Table 2: Results for iohexol concentration in calibrants and QCs, measured on ChromasterUltra Rs and Nexera X3, compared to the theoretical concentrations

results show the standard deviation and bias calculated from the mean of the coefficient of variation (CV) between each duplicate. For the inter-assay precision, the accuracy and deviation of the obtained results for patient sample on the Hitachi ChromasterUltra Rs referenced to the Shimadzu Nexera X3 are calculated (Table 4).

The test replicated with the two instruments shows coefficients of variation in a range of 0.1 % and 12.5 % (Figure 4). These results are acceptable to conclude on the reproducibility of the Nephrolyx IVDx between the ChromasterUltra Rs and the Nexera X3.

GFRx calculation

The GFR is calculated using the GFRx Software Module integrated into the Digital Nephrology Platform DNPx, developed by Nephrolyx (Figure 5). The patient sample presented in Table 4 was used to calculate the mGFR with the iohexol concentrations obtained from the ChromasterUltra Rs and the Nexera X3 (Figure 6). Deviations <= 3 % in the GFRx (multiple sampling point) and Jacobson (single sampling point) calculations, using the concentrations obtained from two instruments, are observed. Clinically, such a deviation between results is of low relevance.

Mastering accuracy and abolishing deaths related to kidney disease

After a direct comparison of the standard curves created on the ChromasterUltra Rs (Hitachi) and the Nexera X3 (Shimadzu), the calibrants and QCs measurement and the well-to-well comparison, it can be concluded that the Nephrolyx IVDx kit showed highly accurate and robust results on both devices.

Additionally, the Nephrolyx IVDx demonstrates that a CE-compliant solution can be established in laboratories to deliver fast and accurate results, enabling GFR mea surements in daily clinical practice according to the new KDIGO CKD 2024 Guideline.

The vision is to provide hospitals and universities worldwide with this new method and make the number of 1.3 million kidney disease related deaths annually a thing of the past as well as guesswork and poorly-dosed medication that causes stress to already exhausted patients.

Figure 4: Direct comparison of iohexol concentration per well between ChromasterUltra Rs and Nexera X3 with calculated coefficient of variation (CV %)

Sample name	Average measured concentration on Chromaster-Ultra Rs [µg/mL]	CV [%] between duplicates (Chromaster-Ultra Rs)	Average measured concentration on Nexera X3 [µg/mL]	CV [%] between duplicates (Nexera X3)	Accuracy [%] (Chromaster-Ultra Rs to Nexera X3)	Deviation [%] (Chromaster-Ultra Rs to Nexera X3)
Patient T0	313.84	0.1 %	296.28	0.9 %	105.9 %	5.9 %
Patient T1	181.40	1.0 %	172.54	0.2 %	105.1 %	5.1 %
Patient T2	124.94	0.9 %	123.90	1.0 %	100.8 %	0.8 %
Patient T3	100.58	1.6 %	98.19	0.3 %	102.4 %	2.4 %
Patient T4	75.83	0.1 %	73.59	1.9 %	103.0 %	3.0 %
Patient T5	58.61	1.1 %	56.17	3.7 %	104.3 %	4.3 %

Table 4: Direct comparison of iohexol concentrations for one patient at different sampling time points after iohexol injection (T0 to T5) between ChromasterUltra Rs and Nexera X3 using the Nephrolyx IVDx kit

Note

For more information and references, please refer to the digital version of this edition.

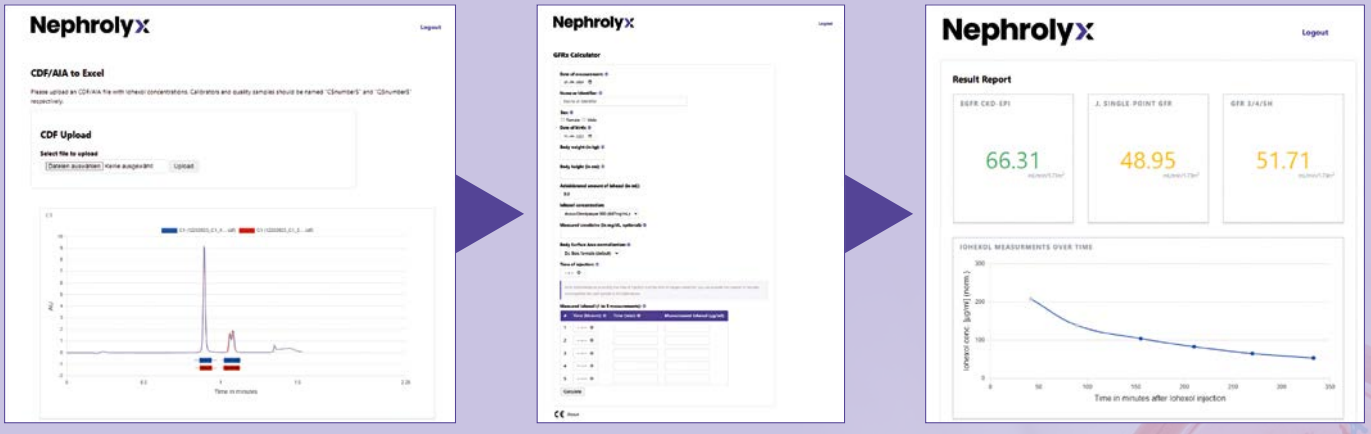
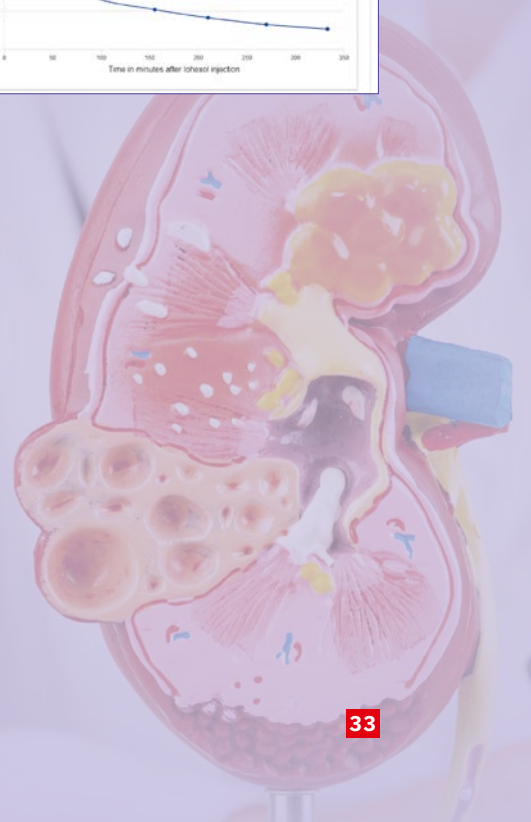


Figure 5: Digital Nephrology Platform (DNPx) with integrated GFRx Software Module

GFRx Calculator

GFRx Calculator

Figure 6: GFRx and Jacobson calculation based on ChromasterUltra Rs results (left) and Nexera X3 results (right)



Uncovering the hidden potential

Researching pesticides, a lab stumbled on something interesting about supercritical fluid chromatography (SFC)

Víctor Cutillas,
European Union Reference Laboratory for Pesticide Residues in Fruit & Vegetables,
University of Almería

At the University of Almería in Spain, Víctor Cutillas and a team of analytical chemists were using the conventional standard method to analyze pesticide residues in fruits and vegetables. In the interests of time, the team was also applying a secondary, "back-up" method. In the process of doing their work, however, the team became aware of how well the secondary method was working. Was it perhaps performing even better than the primary method? Víctor Cutillas decided that he needed to know the answer to that question. So he embarked on a comparative investigation of the two systems.

Víctor Cutillas analyzes pesticide residue at the EU Reference Laboratory for Pesticide Residues in Fruits & Vegetables (EURL-FV) at the University of Almería in Spain. Pesticide residue analysis is critical for ensuring food safety and regulatory compliance, and the EURL-FV plays a crucial role in keeping consumers safe by improving the quality, accuracy and comparability of the food-safety test results.

The most commonly used method in pesticide residue analysis is reverse-phase liquid chromatography in combination with tandem mass spectrometry (LC-MS/MS). This is due to its robustness and broad applicability for semipolar and some thermolabile pesticides. However, supercritical fluid chromatography (SFC) – widely used in areas such as the pharmaceutical sector – is also applied occasionally in pesticide residue analysis because of its advantages, e.g. in ionization.

One day, Víctor and the EURL-FV team were very busy with their analyses, using both LC-MS/MS and SFC-MS/MS methods. As they ran more and more samples, they began to notice that thermolabile compounds, which usually suffer in the ion source, showed remarkable stability using SFC. In addition, certain chemical groups displayed far better sensitivity using SFC than they had ever seen using LC. And, while they expected some reduction in matrix effects using SFC, the results often went beyond their expectations – sometimes dramatically.

Comparative performance of LC and SFC for multiresidue pesticide analysis in food

Wondering whether the potential benefits of SFC for their work had been underestimated, Cutillas decided to conduct a formal study of the two methods. The study was to directly compare the performance of LC and SFC on 215 pesticides in fruits and vegetables using the same mass spectrometer (a Nexera UC coupled to an LCMS-8060, both from Shimadzu). The focus was on sensitivity, matrix effects and ionization efficiency across different food samples, including tomato, leek, onion and orange. →

Identified compounds

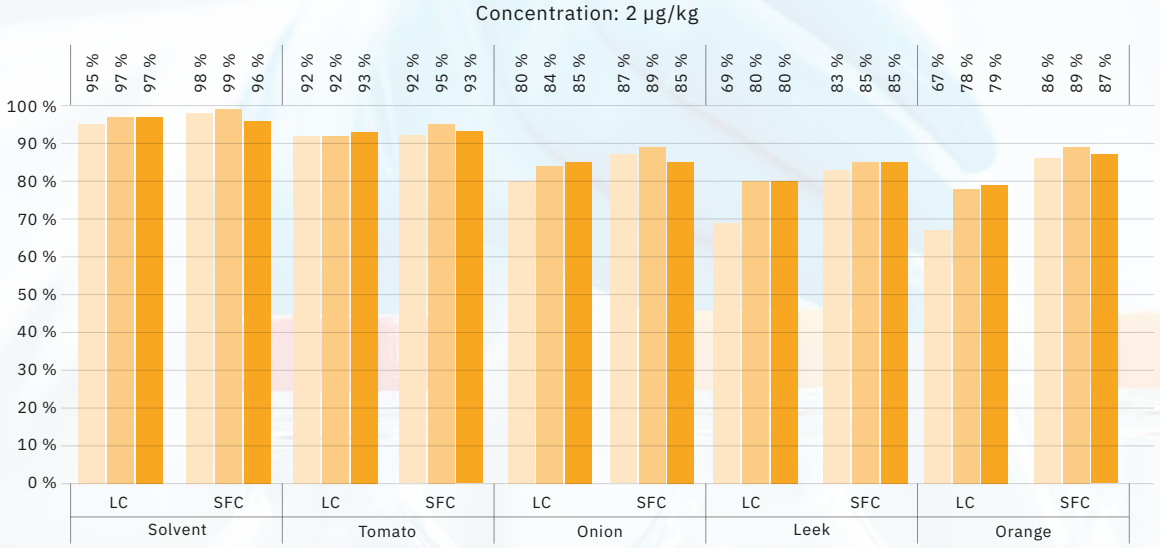


Figure 1: Percentage of identified compounds at the three ion source temperatures tested. The 215 pesticides were evaluated by both LC and SFC in solvent and in tomato, onion, leek and orange matrices.

Sensitivity and ion source temperature

The study assessed the optimum electrospray ionization (ESI) interface temperatures for both techniques, summarized in Figure 1. LC exhibited slightly higher sensitivity at 350 °C. In comparison, SFC showed consistent results across a broader temperature range, with 99 % of pesticides determined in a pure solvent and 95 % in the tomato matrix even at lower temperatures, such as 200 °C and 125 °C.

In complex matrices such as leek and onion, the differences became more pronounced. For leeks, LC identified 80 % of pesticides at 350 °C but only 69 % at 125 °C. SFC, however, maintained a higher identification rate of 83–85 % across all temperatures. This indicated that SFC can be more versatile in handling various ion source temperatures without compromising sensitivity, offering significant benefits for laboratories dealing with a variety of food samples.

Chemical group sensitivity

Different chemical groups responded uniquely to each chromatography technique. For instance, among the 70 compounds showing higher sensitivity in LC, 27 % were organophosphates.

Conversely, among the 77 compounds showing higher sensitivity in SFC, 22 % were triazoles, such as bromuconazole and cyproconazole. The nonpolar nature of the supercritical CO_2 used in SFC, coupled with its unique elution mechanism, likely contributed to this enhanced sensitivity.

The average $logP_{ow}$ values were similar for both techniques, indicating that polarity alone does not determine the best technique for each pesticide.

Matrix effects and ion suppression

Matrix effects can significantly impact the accuracy and reliability of pesticide residue analysis. The study revealed that SFC had a lower degree of ion suppression than LC, particularly in complex matrices such as leek, onion and orange. For instance, in the leek only 5 % of pesticides in LC had low or non-existent matrix effects (0–20 %), whereas 28 % of pesticides in SFC fell into this category.

	M.E. (%)	LC-MS/MS	SFC-MS/MS
Tomato	0–20 20–50 > 50	90 % 8 % 1 %	83 % 13 % 4 %
Onion	0–20 20–50 > 50	11 % 28 % 61 %	29 % 21 % 50 %
Leek	0–20 20–50 > 50	5 % 23 % 72 %	28 % 22 % 50 %
Orange	0–20 20–50 > 50	7 % 53 % 39 %	53 % 18 % 28 %

Table 1: Percentage of the 215 pesticides affected by matrix effects in tomato, leek and orange matrices using reverse-phase LC and SFC

In the orange matrix, the difference was even more striking. Only 7 % of pesticides analyzed by LC had low matrix effects, compared to 53 % for SFC. These findings are crucial, as they demonstrate that SFC is more effective at reducing ion suppression caused by coextracted matrix components. Furthermore, the different elution profiles of SFC and LC play a vital role, with SFC's unique mechanism reducing the overlap between analytes and interfering substances, thereby enhancing sensitivity and identification accuracy (Figure 2).

Cutillas' comparative study revealed that SFC offers distinct advantages in analyzing complex food matrices with high coextracts. Its ability to maintain sensitivity at lower ion-source temperatures makes it particularly suitable for thermolabile compounds. With its consistent high-sensitivity performance across a range of temperatures and lower matrix effects, SFC provides a robust and versatile alternative for modern pesticide residue analysis.

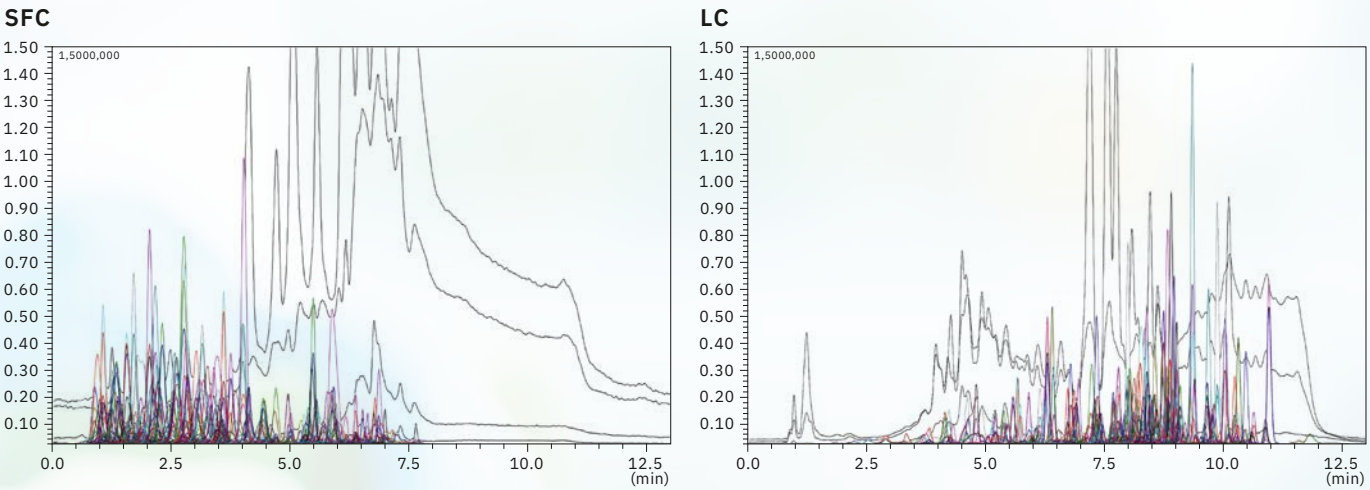


Figure 2: Total ion chromatograms (TIC) of the orange matrix overlapped with the chromatograms of the multiresidue methods at the concentration level of 5 µg/kg

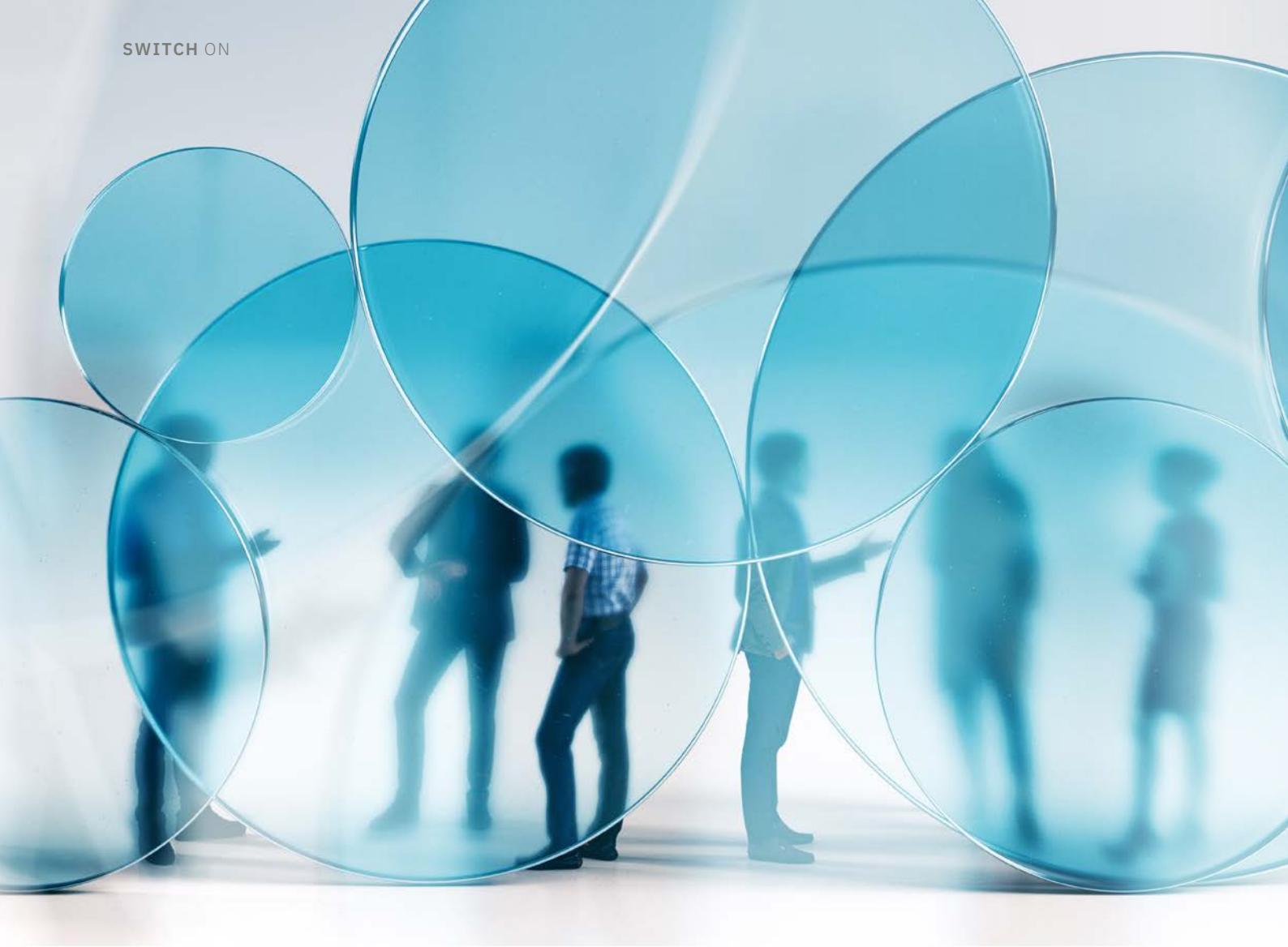
Cutillas also notes that SFC is a more sustainable method of analysis as it produces less waste. The CO_2 it uses is recyclable, whereas LC relies on higher amount of organic solvents. In addition, by using equipment such as the Nexera UC, labs can run both methods on the same platform without additional hardware.

Knowledge is a complex construct, and sometimes what we think we "know" is only a mask for our ignorance. In this case, what was thought to be a backup turned into a breakthrough. The true knowledge had been sitting there all along, waiting for a curious scientist to notice it.

And now, thanks to Víctor Cutillas and the team at the EURL- FV in Spain, a more efficient, more sensitive and more sustainable way to ensure food safety has been revealed. The result is progress: for labs, for science and for humanity.

Note

For more information and references, please refer to the digital version of this edition.



Products made of acrylic glass have become an integral part of our everyday lives – from watch crystals to submarine pressure hulls. Hopefully, those transparent screen dividers from the pandemic are forever a thing of the past. Depending on whether a crystal-clear view or frosted glass is required: The cloudiness of acrylic glass is defined as its "haze value", which is determined according to the ASTM D 1003 standard. The haze value can be determined using a UV-Vis spectrophotometer (or "spectrometer" for short). However, the measurement process is cumbersome and there isn't enough time in everyday laboratory work to manually analyze the required data. That's why it became necessary to automate the process while keeping the requirements of the standard in mind.

Acrylic glass is a plastic that has been used in a wide range of applications since its invention. And no wonder, not only is the material lightweight, it can also be thermoformed without any issues. In most cases, plastic glass replaces mineral glass, meaning it should be just as transparent. However, translucent acrylic glass is also sometimes used, for example as a diffuser in LED panels or for privacy lighting solutions (Figure 1). The degree of cloudiness of an acrylic glass pane is therefore an important specification for its future use and must be checked during quality control.

According to the ASTM D 1003 standard, the optical quality of a plastic pane is given as a haze value. This is defined as the percentage ratio of diffuse to total transmission of visible light through the sample. Put simply, the lower the haze value, the clearer the material.

No cloudy outlook for acrylic glass

Easy to determine haze value thanks to LabSolutions UV-Vis

Dr. Benjamin Thomas, Shimadzu Europa GmbH

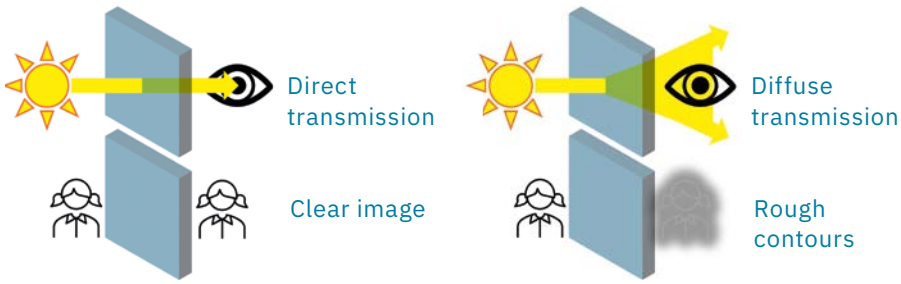


Figure 1: Comparison of a transparent and a translucent acrylic glass pane. The higher the diffuse transmission, the more blurred the contours appear through the pane.

The transmission values needed to calculate the haze value are either measured with a special haze meter, which is described in detail in the standard, or calculated from spectra taken with a UV-Vis spectrometer.

Haze meters vs. spectrometers

The biggest difference between a haze meter and a spectrometer is the monochromator. It is located in a spectrometer between the light source and the sample and splits the white light from the light source into the different wavelengths – in the case of visible light, from 380 nm to 780 nm (Figure 2).

A haze meter does not have a monochromator, so it only ever measures a single value: the brightness of the light source behind the sample.
On the other hand, a spectrometer measures the transmission of the sample for each wavelength. This is →

advantageous as other parameters can be calculated from the spectrum in addition to the haze value, such as the color or the transmission of ultraviolet or infrared light in particular. Depending on the specific application, these values are required by other standards, such as DIN EN 410 for the color fastness and thermal insulation of window glass.

But it's precisely this versatility that is the spectrometer's downfall: Determining the haze value requires extra work that a haze meter avoids. Calculation and evaluation still have to be done manually to a large extent. This meant that laboratories were previously faced with the decision of either purchasing a haze meter, which only serves one purpose, or putting up with the extra effort.

Calculating the haze value

Both instruments can measure the total transmission by imaging all light onto the detector and the diffuse reflection by imaging only the light scattered by the sample onto the detector. In this way, a data set is made up of the raw data from four measurements:

1. Empty measurement with measurement setup for the entire transmission, $T_1 \sim 100\ \%$
2. Total transmission through the sample, $T_2 \leq 100\ \%$
3. Empty measurement with measurement setup for diffuse transmission, $T_3 \sim 0\ \%$
4. Light scattered on the sample, $T_4 \leq T_1$

Since no light is reflected, absorbed or scattered by a sample during an empty measurement, the transmission measurement value of the empty measurement ideally corresponds to 100 % for the setup for the total transmission and ideally 0 % for the setup for the measurement of the diffuse transmission. If the measurement is transmitted through a sample, reflection and absorption will result in the total transmission equally less than 100 %. The measured value of the diffuse transmission depends heavily on the haze value and ranges between 0 % (0 % haze) and the measured value of the total transmission (100 % haze).

For spectrometer measurements, the entire spectrum must first be converted into a single transmission value for each of the steps.

The corrected haze value is calculated from these four individual measurements by subtracting the haze value of the empty measurement (ideally 0) from the haze value of the sample. This last calculation step is usually not possible from within the spectrometer software, instead requiring the raw data to be exported to evaluation software such as Microsoft Excel, MathWorks MATLAB or OriginLab Origin. This manual step is highly vulnerable to errors.

The automation process

To make this time-consuming process easier for users, the LabSolutions UV-Vis software had to be expanded and automated accordingly. After careful consideration of ASTM D 1003, an Excel template was first drawn up for the evaluation after manual export of the data and then expanded to include automatic measurement.

In the now customized software, an Excel template with prepared formulas or macros can be used to simplify the creation of the final report. For use in a regulated environment (21 CFR Part 11), Shimadzu offers the LabSolutions Manager multi-data reporting tool, a spreadsheet application with full traceability thanks to an audit trail and electronic signatures. Prepared haze templates can be requested for both cases.

Laboratory software in practice

Four differently clouded acrylic glass panes with the corresponding transmission spectra and haze values (Figure 3) are used to demonstrate the effect of the haze value. They were placed in front of a photo of the face of Genzo Shimadzu Sr., the founder of Shimadzu.

The top sample with a haze value of around 0 % has almost no diffuse transmission and the image is clearly recognizable. While the total transmission remains almost the same for all other samples, the measured value of the diffuse transmission increases with the haze value; the contours of Gen-san's face become increasingly blurred. In the lowest sample with almost 100 % haze, the contours are barely recognizable; the curves for total and diffuse transmission are almost the same.

The measurement of the four required raw data sets and the analysis are now simplified by a dedicated measurement program. It guides the user through the various steps and ensures that the raw data is entered into the report template in the correct format and analyzed.

The graphical user interface of this program is shown in Figure 4. Clear instructions guide the user through the analysis step by step and illustrations, if required. The relevant metadata (Is it a sample or empty measurement? Should the total or diffuse transmission be measured?) are automatically generated in the background and

forwarded to LabSolutions UV-Vis. A report is then generated using Excel or a multi-data report, depending on the regulatory requirements, where the formulas described here are already stored in the report template.

This eliminates the need to transfer the data to an additional program for evaluation. Automating the final and decisive calculation step saves time and helps prevent errors that can occur during transmission.

The haze value of acrylic glass is decisive for the technical application of the respective product. A clear lens with a low haze value allows an unclouded view, while a cloudy lens with a high haze value blurs the contours of any objects behind it. Manually determining the haze value requires some background knowledge. This has been facilitated by a program with automated measurements and clear instructions that now allows less experienced users to carry out analyses. The LabSolutions UV-Vis software allows automation via macros and the export of data to Excel. With the package of device, software and report templates presented here, this process is automated. Now, all the user has to do is enter the samples and press “Start” to receive a finished report.

Note

For more information and references, please refer to the digital version of this edition.

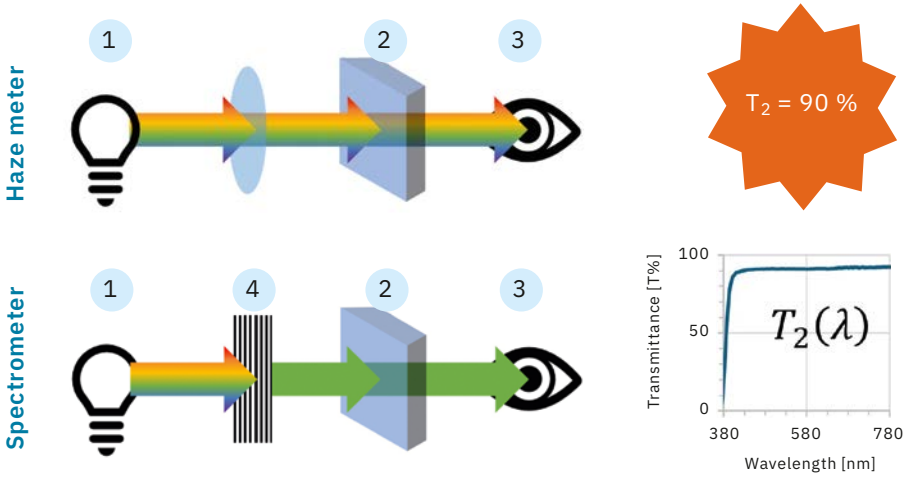


Figure 2: Schematic diagram of a haze meter according to ASTM D 1003 (top) and a spectrometer (bottom). Both instruments contain a light source (1), a sample (2) and a detector (3), but the spectrometer also has a monochromator (4).

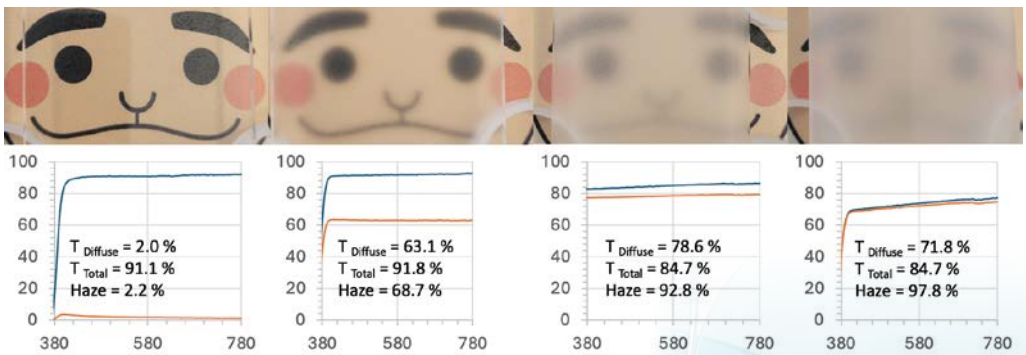


Figure 3: Examples of different haze values, increasing from the top to the bottom sample. While the total transmission (blue curve) is almost identical for all samples, the diffuse transmission (orange line) increases when the haze value increases.

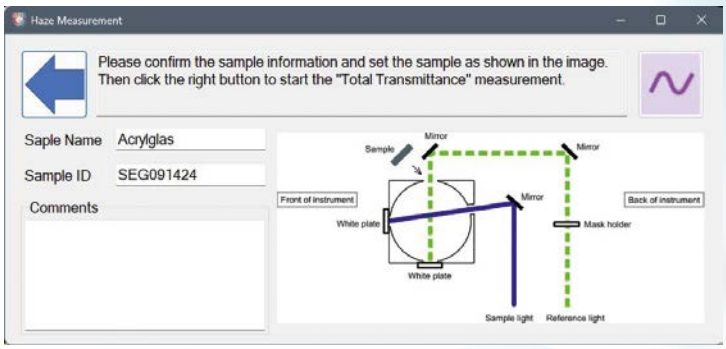


Figure 4: Graphical interface of LabSolutions UV-Vis Haze macro with clear instructions for preparing measurements

A contribution to climate protection

Analytical process control in bioethanol production

Martin Meyer, Shimadzu Europa

In light of the fight against climate change, bioethanol as a fuel has become increasingly important in recent years. However, since the raw material could also be used as animal feed or a foodstuff in most cases, bioethanol producers have a great responsibility to utilize the raw materials as efficiently as possible. Accurate control of the predominantly biological process is crucial for this. This article provides an insight into the production process from the raw material to the finished ethanol. Can technology from Shimadzu help optimize the process?

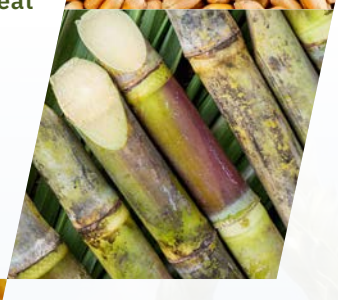
Half past eight in the morning – a busy time at gas stations. When drivers stand in front of the pump, they have a choice: E5 or E10? What many don't know is that the E stands for "ethanol" (or simply "alcohol"), and the number indicates the amount of ethanol in that product – 5 or 10 %. The EU is in the continuous process of increasing the amount of biofuels used (such as bioethanol), as the higher admixture of products obtained from renewable sources is intended to improve the CO_2 balance of road traffic.

Although fuels from renewable sources also release CO_2 into the environment, the plants from which they are obtained have previously absorbed a significant amount from the environment. As a result, they contribute less to CO_2 pollution than fossil fuels overall. However, the production of bioethanol is not straightforward. Bioethanol is produced from plants with a high starch or sugar content.

When it comes to producing ethanol, it is important to distinguish between raw materials that contain sugar and those that contain starch. Although starch also consists only of linked glucose molecules, additional steps are required to break down the starch and convert it into smaller sugar molecules. The enzyme alpha-amylase breaks down the starch into smaller chain pieces (polysaccharides), and the enzyme glucoamylase releases the glucose from these polysaccharides. Raw materials containing sugar, such as sugar cane and sugar beet, can be metabolized directly into ethanol using yeast fungi.

→

wheat



sugar cane

corn

grapes

Figure 1: Substances fermented to produce ethanol: wheat, sugar cane, corn and grapes

Monitoring the fermentation process

The biological process in which yeast fungi convert sugar to ethanol is known as fermentation. During this process, one molecule of glucose is chemically converted into two molecules of ethanol and two molecules of CO_2.

$$C_6H_{12}O_{6(aq)} = 2 \cdot C_2H_5OH_{(aq)} + 2 \cdot CO_{2(aq)}$$

Despite the apparent simplicity of the formula, the success of the process depends on a number of critical factors, such as the composition of the raw material, temperature, time as well as the pH value. That's why it is important to monitor the process regularly in order to make the conversion to ethanol as efficient as possible. The ability to identify the different types of sugar, determine their concentrations and control the ethanol content plays a decisive role in this regard. During the process, various organic acids can also form which, although present in small quantities, have a huge impact on the pH value. An increased content of organic acids and the resulting low pH value can stop the fermentation process altogether. It is important to keep an eye on all these factors in order to recognize potential problems at an early stage and ensure that the fermentation process runs smoothly. This is the only way to obtain the largest possible amount of ethanol from the raw material.

Determining the types of sugar poses a particular challenge, as many of these substances are very similar in terms of their chemical composition. Fructose and glucose, for example, have the same chemical formula but differ in their structures.

The analysis is further complicated by the fact that most sugars cannot be differentiated using a UV- VIS detector. Furthermore, organic acids are usually determined applying different chromatographic methods than those for sugars. Therefore, it is extremely difficult to combine and analyze all components with one single method.

With the Shim-pack SCR-102H column, Shimadzu offers a solution that enables both ion exclusion and size exclusion chromatography. The column can separate sugars and organic acids at the same time so that these can be identified and their quantities determined. The suitability of the column was tested by preparing and measuring real fermentation samples.

Conducting the test

The starchy raw materials wheat and corn and the sugary raw materials sugar cane and grapes were fermented. The following procedure was used for raw materials that contain starch: Firstly, the dry corn and wheat grains were crushed to a fine powder in a sample mill. After this, 40 g of the respective powder were dissolved in 200 g of water. This mixture was placed in a flask, and approx. 0.2 g of alpha-amylase were added while stirring continually. To ensure optimum conditions for the enzyme, the mixture was heated to 70 °C and left to sit at this temperature for at least 3 hours. The temperature was then lowered to 55 °C, 0.2 g of glucoamylase were added and also left for at least 3 hours. After this step, all samples were treated in the same way. Both the crushed sugar cane and grape extracts and the previously treated wheat and corn digests were mixed with 0.5 g of yeast and left to ferment at room temperature.

During the entire process, samples were taken from the digests at regular intervals. These samples were first centrifuged to separate the solid components. Next, a portion of the supernatant was filtered through a syringe pre-filter (0.45 µm). If the samples could not be measured immediately, they were stored at –20 °C to interrupt the fermentation process.

The samples prepared in this way were used directly for measurement under the analysis conditions listed in Table 1.

The retention times of the peaks were assigned by measuring individual standards, and calibration curves were created by measuring different concentrations. →

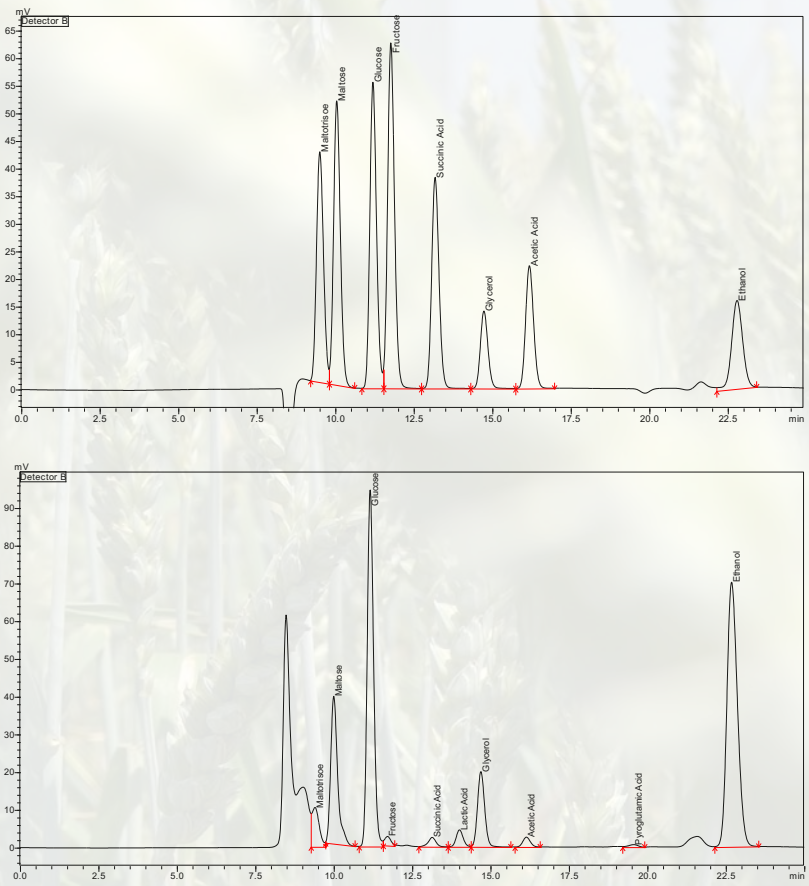


Figure 2: Standards (top) and genuine fermentation sample (bottom) on the Shim-pack SCR-102H with RID detector

Analyseparameter	
System	LC-2040
Column	Shim-pack SCR-102H
Mobile phase	water + 5 mM sulfuric acid
Column oven	50 °C
Run time	25 min
Flow rate	0.65 mL/min
Injection volume	10 µL
Detection	
RID	RID-20A
Cell temperature	50 °C
PDA	LC-2040 PDA
Cell temperature	50 °C

Table 1: Analysis parameters

The data obtained in this way can be used to visualize the entire fermentation process, as shown in Figure 3 for the starting material corn. The figure shows that the sugars (maltotriose and maltose) can only be identified after alpha-amylase is added. This is followed by a sharp increase in glucose after glucoamylase is added. Ethanol is only produced after the yeast has been active for some time. Furthermore, it is clearly visible that the decrease in glucose is associated with a simultaneous increase in ethanol content.

While the initially formed sugars are completely broken down, ethanol becomes the main product after some time. The glycerine and acetic acid content also increase with the ethanol. Glycerine is a by-product of alcoholic fermentation and is produced by yeast. Glycerin contributes, among other things, to the viscosity and consistency of fermentation products like wine. Acetic acid is produced by the universally occurring Acetobacter, which oxidize ethanol to acetic acid.

In contrast, sugary substances do not require the addition of amylase or glucoamylase, as the sugar they contain can be converted directly by the yeast. Figure 4 depicts the fermentation of grapes. Grapes contain roughly equal amounts of glucose and fructose. However, the yeasts favor the glucose, which is why it is broken down more quickly.

Other interesting raw materials are sugar cane and sugar beet, with sucrose being the predominant sugar in these plants. Sucrose, also known as granulated sugar or table sugar, is a disaccharide in which glucose and fructose are combined, although this bond is cleaved in an acidic environment. That means a column that works with an acidic mobile phase, as is the case with the SCR-102H, cannot be used for analyzing materials containing sucrose. For this reason, the carbohydrate-specific column Shim-pack SCR-101N, which can separate sugar in pure water, was used additionally. Figure 5 depicts the comparison of the sucrose, glucose, fructose and ethanol standards on

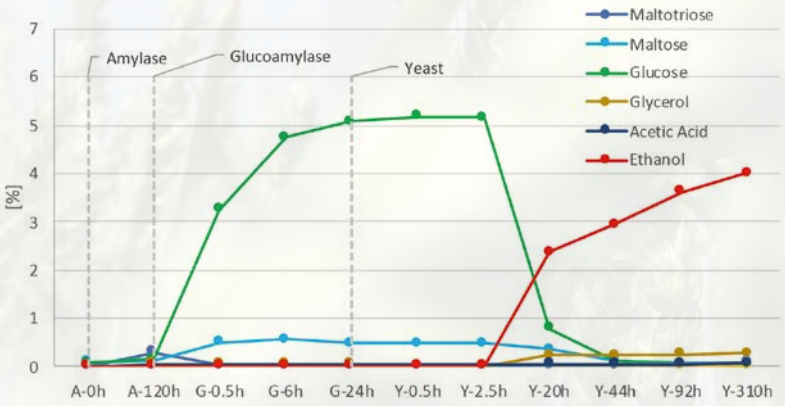


Figure 3: Fermentation process of a corn sample

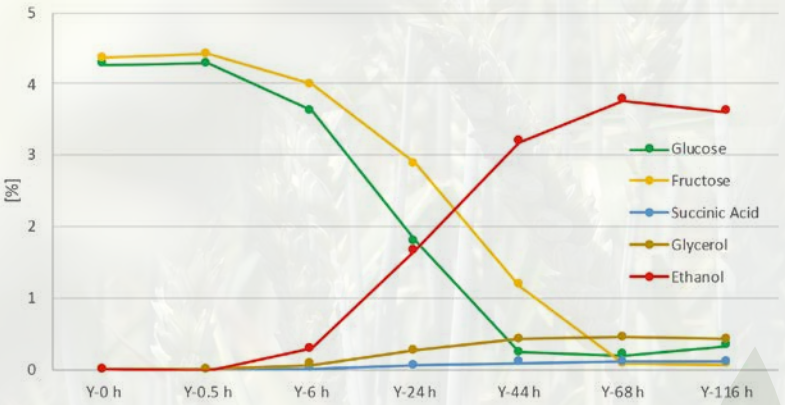


Figure 4: Grape fermentation process

the two columns. The decomposition of the sucrose can be clearly recgonized when using the acidic mobile phase, while the SCR-101N shows clear peaks. Since organic acids cannot be separated with the SCR-101N, it is recommended in this case to analyze the sample on both columns for a comprehensive overall picture. Shimadzu offers a dual-injection system as a complete solution, allowing the sample to be analysed simultaneously on two different columns and detectors on a single HPLC system.

Incidentally, only alcohol contents of around 15 to 20 % can be achieved during fermentation, since alcohol above this concentration acts as a cell poison and causes the yeasts to die. However, this alcohol content is not high enough to fuel engines, which is why the ethanol is then separated from water and other substances by distillation. And when it has been added to petrol, drivers have a choice at the gas station: E5 or E10?

High efficiency thanks to advanced analysis

The production of bioethanol is becoming increasingly important in a world focused on sustainability. Research is already being carried out into second-generation bioethanol made from cellulose. The complex process of ethanol production requires precise control in order to achieve optimum results. With Shimadzu's advanced analytical capabilities, namely the Shim-pack SCR-102H and SCR-101N columns, the whole process can be monitored. This increases efficiency, which makes an important contribution to conserving resources. After all, Shimadzu always strives to offer the best products and to promote environmentally friendly working practices.

Note

For more information and references, please refer to the digital version of this edition.

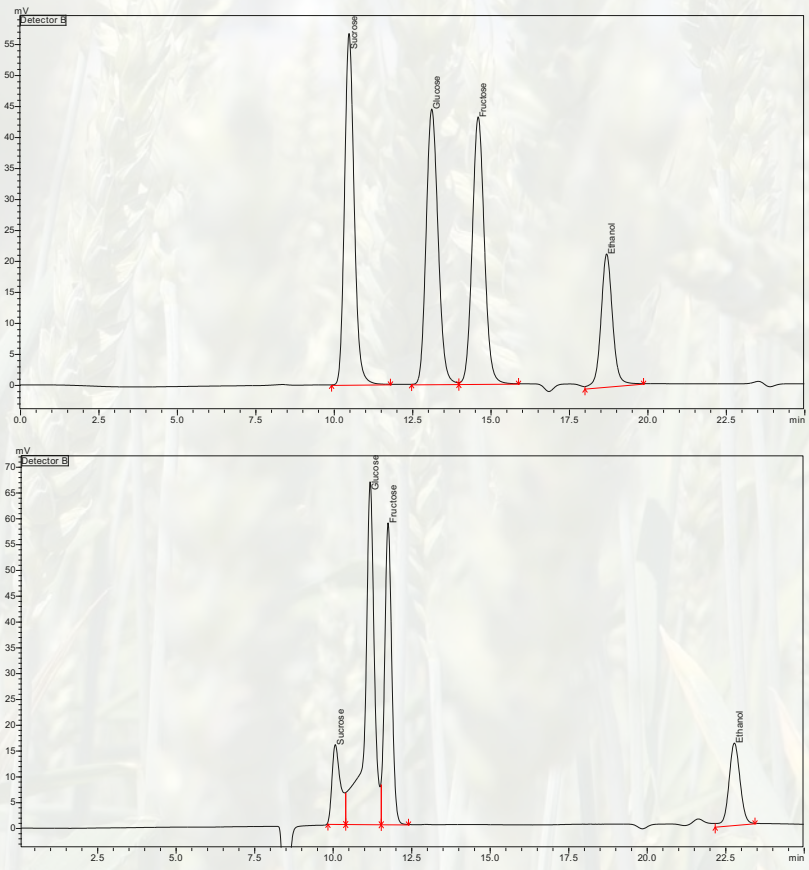


Figure 5: Comparison of sucrose, glucose, fructose and ethanol standards on the SCR-101N (top) and SCR-102H (bottom)

JEC
Paris, France
March 4–6, 2025

ANAKON
Leipzig, Germany
March 10–13, 2025

SETAC
Vienna, Austria
May 11–15, 2025

EUROMEDLAB
Brussels, Belgium
May 18–22, 2025

HPLC
Bruges, Belgium
June 15–19, 2025

METABOLOMICS
Prague, Czech Republic
June 22–26, 2025

secrets of science magazine — Customer Magazine of Shimadzu Europa GmbH, Duisburg

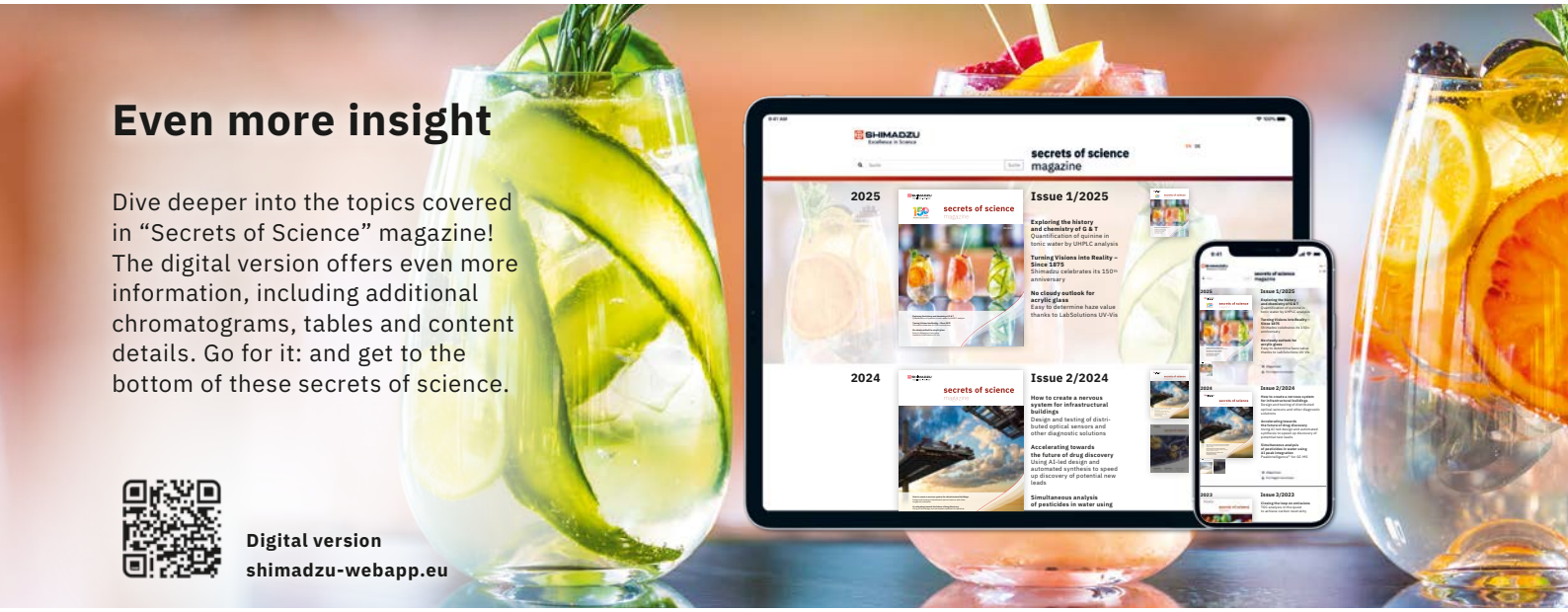
Publisher — Shimadzu Europa GmbH
Albert-Hahn-Str. 6–10
D-47269 Duisburg
Tel.: +49(0)203 7687-0
shimadzu@shimadzu.eu
www.shimadzu.eu

Editorial Team — Uta Steeger, Sonja Wischnewsky, Andrea Wagner-Neumann, Christoph Fischer, Christopher Brünn

Design — Bartenbach AG
Kaufmannshof 1
D-55120 Mainz

Circulation — German: 4,450
English: 3,700

@ShimadzuEurope



Even more insight

Dive deeper into the topics covered in “Secrets of Science” magazine! The digital version offers even more information, including additional chromatograms, tables and content details. Go for it: and get to the bottom of these secrets of science.

Digital version
shimadzu-webapp.eu

Printed on 100 % recycled paper