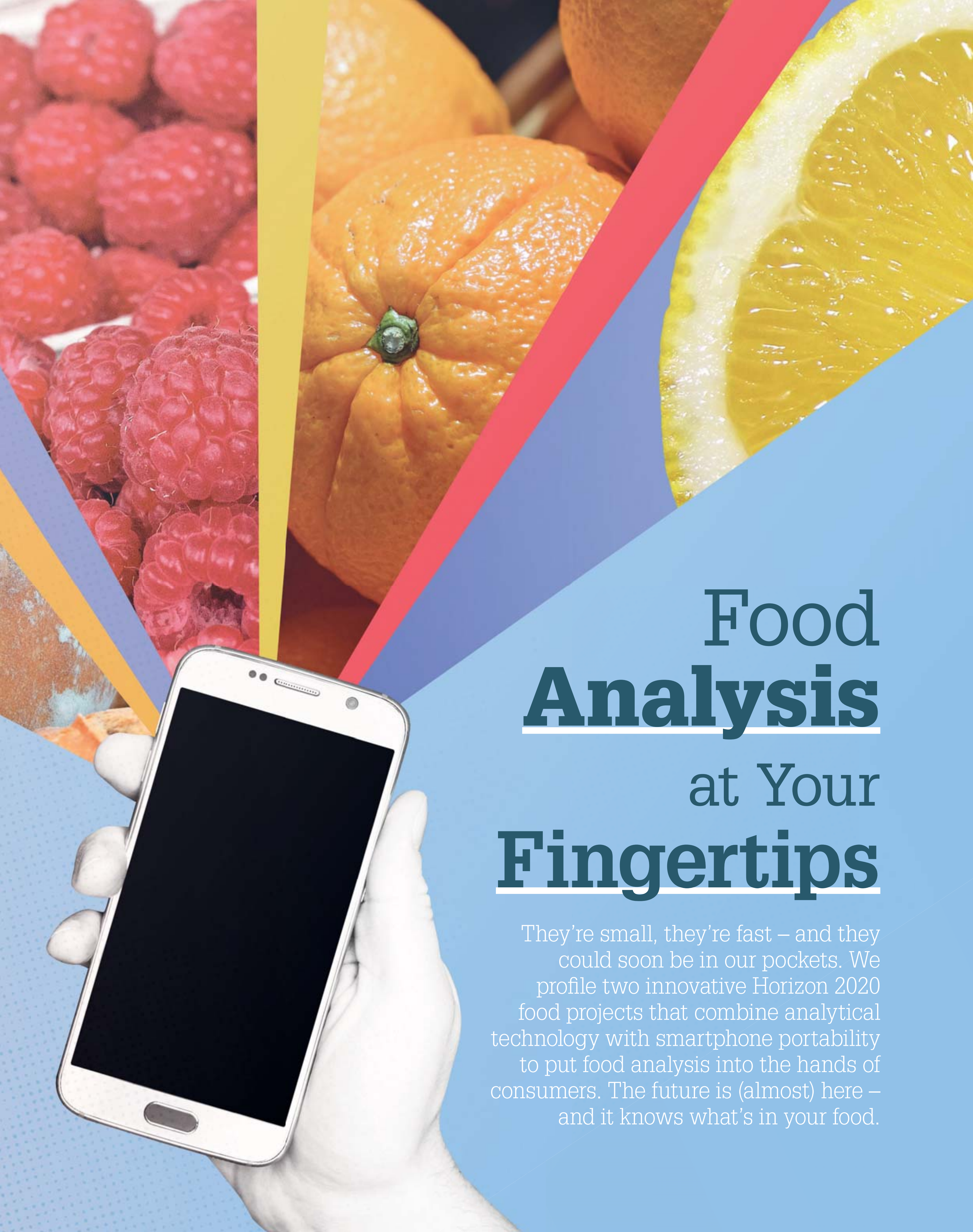


Food **Analysis** at Your **Fingertips**

They're small, they're fast – and they could soon be in our pockets. We profile two innovative Horizon 2020 food projects that combine analytical technology with smartphone portability to put food analysis into the hands of consumers. The future is (almost) here – and it knows what's in your food.

SHOOT FIRST, ASK QUESTIONS LATER

Food researchers are joining forces with hardware and ICT developers and mobile phone app writers to build a new type of scanner. Integrating three sensor devices with advanced software, the PhasmaFOOD will provide miniaturized and on-the-spot analysis for the detection of food spoilage and food fraud.

With Yannick Weesepoel, Researcher Food Authenticity – Food Scanners, RIKILT, Wageningen University & Research

The whole idea of PhasmaFOOD is to combine different light sensors into an integrated scanner system and build a consumer app around it to make a new generation of light food scanner. So-called heterogenous photonics is the ultimate hardware goal, which basically means that all the elements of a photonic system are fabricated on a single chip to meet size and cost requirements. The device will host three sensor types: two spectrometers and one micro-camera. In addition, three light sources will be integrated with the device to support its sensing functionality. A dedicated PhasmaFOOD mobile app will allow end-users to interact with the device, and the captured data will be communicated via wireless mobile networking to the PhasmaFOOD backend. Analysis results will immediately be sent to users, who will be able to access them at any time and from any location.

Why has portable food analysis suddenly become such a big thing? I think in one way it's very much technology driven; until now, it was not possible to make a chip with an infrared sensor small or cheap enough. It was also not possible for smartphones to operate in such a way. The people making smartphone technology five or six years ago already recognized that people would be using their phones to a much greater extent in the future. Me? I can't remember how good my phone was five years ago – actually, I don't even remember if I had a smartphone! But the interest in food analysis is also consumer-driven; people are suddenly more interested in "scanning" their food – the idea of doing your own analysis, in a simple way, triggers something in people.

A NEED FOR SOMETHING NEW

When I started here at RIKILT, there were many research position vacancies available. I'd already worked with mass spectrometry during my PhD and wanted to try something new. I'd heard a little about scanners, and thought, "Why not go in that direction?" The fact that the technology would be used by people at home rather than stay in the lab very much appealed to me. Most of the time, during my PhD, this was not the case; you did fundamental, very technical research, which I didn't always find very satisfying. I really like to make things which will be used in real life.

So when I started working here about three years ago, I did some preliminary work on chicken meat. Using a very simple infrared scanner, we attempted to find the water and protein content of the chicken, with the aim of finding out more about how (and how long) it had been stored. The consortium of PhasmaFOOD (George Koutalieris, from INTRASOFT International and Paraskevas Bourgos, from WINGS ICT) began looking for expertise on testing the PhasmaFOOD scanner – and that's how I got involved.

I started acquiring advanced miniaturized IR sensors from Viavi Solutions (formerly JDSU). We began partnering with more companies, and the publicity on food scanners started to build. People started to understand the objective: to revolutionize the use of infrared. It was the beginning of a movement from the lab (a controlled environment) to something completely uncontrolled; from very exact databases to big databases built into an app by non-specialists. Of course, infrared sensors are already being built into phones, but there are still many things you can't do, such as measuring allergens, gluten, lactose or toxins.

Current food scanners – Spectral Engines (the winner of the European Commission's Horizon 2020 food scanner award), SciO (ConsumerPhysics), or TellSpec (the runners up) – are all based on near infrared (NIR) technology. However, NIR spectroscopy is actually somewhat limited in this application; you can scan the macrocomposition of products and even find components that are minimally present (0.1–1 percent). But NIRS struggles to measure very low concentrations of compounds or food spoilage, so more advanced applications are out of reach. We need more information, and that's why we need a new food scanner.

PERFECT SENSE

Our device works much like any vibrational spectroscopic sensor and must be "trained". For example, if you want to know the moisture content of a piece of meat, the sensor must be presented with different reference samples with different concentrations of moisture within an acceptable range to build a spectral database and a multivariate statistics-based algorithm. If the sensor can actually measure moisture content in a new sample, your model works correctly. If not, you must expand the database to cover more variation in the food samples you present to the sensor. Variation is always a problem with food analysis; to build a functional database, you have to cover a significant amount of natural variation within a given food product. Unlike the pharmaceutical industry, which tends to have narrow concentration windows for all chemicals present, potential variation in food sometimes feels infinite.What is the impact of a different country of origin, a different farm – or even a different cow?

FOOD FOR THOUGHT

Michel Nielen is co-chair of the RAFA 2017 food analysis conference in Prague. Here, he tells us what's on the menu this year.

Can you give us a roundup of RAFA 2017?

RAFA is the leading biannual conference on recent advances in food analysis. In November we expect 800+ participants in beautiful Prague. We usually have a large audience and speaker lineup comprised of people who are active in food contaminants (pesticides, antibiotics, POPs), natural toxins and fraud, but we will also cover growing trends in the world of (advanced) food analysis. Food fraud in particular is an ever increasing issue; a couple of years ago, we had only one session about food fraud, but now it is one of the cornerstones of RAFA.

What's new this year?

Human biomonitoring is one very interesting new topic that will be covered in RAFA 2017. In current duplicate diet studies, half of the food is consumed, the other half sent to labs for food analysis, so they can measure contaminants or other compounds that have been ingested. You might also collect samples like blood or urine to find a link between analysis of the product and the consumer/consumption. Nowadays, people are searching for alternative means of finding consumption data with contaminants or nutrition value patterns. There is an emerging trend to use head hair specimens, which is borrowed from the forensic field, where hair has been used for drug testing. Your head hair, which grows 1cm a month, represents a chemical archive – the chemical composition of 1cm of your hair correlates with your food (and drug) intake from the last month. It's an entirely new concept for the food analysis field. In fact, it's relatively novel to see people trying to retrieve food consumption and contaminant exposure data from urine and blood. And so, for the first time, we decided to organize a session called "Human biomonitoring related to food" – and we have arranged some high profile speakers.

In food analysis, the focus is traditionally on foods, food products and intermediate products or raw materials. Such samples are being analyzed in labs in line with legislation; for example, maximum residue limits. But we also need to know more about food intake and consumption patterns, to understand the risk of exposure to food-related hazards.

Are you running a session on portable food sensors?

Yes, the PhasmaFOOD/FoodSmartphone guys will take the lead in organizing an oral session about smart sensing. There'll also be hands-on demos in a dedicated "smart lab", where people can start playing with food scanners and smartphones and do some testing themselves.

What are you particularly looking forward to?

I'm looking forward to the food fraud sessions, as there is a lot of interesting research going on. I'm also very interested in natural toxins; mycotoxins have been studied for many years, but there will be focus on plant toxins, marine toxins and bacterial toxins as well. From the more practical side, multiple pesticide analysis is always a highlight. At RAFA 2015, vendors had instruments in production doing multiple analysis of hundreds or even thousands of food contaminants, in a single analytical run; it's always exciting to look forward to major improvements in mass spectrometry technology both from researchers and instrument vendors.

The project started at the beginning of 2017 with the refinement of the hardware, so the sensors and illumination sources are already available. Design of the prototype – how the electronics, hardware and casing will fit together – is already underway. Designs for the cloud database and the apps have begun, and the team has also performed business case and user case analysis. The main and current analytical task is making reference measurements and using that data to build spectral databases. We are (slowly) testing the sensors for the proposed applications, namely the detection of:

i. mycotoxins and aflatoxins in nuts and grains;
ii. food spoilage and shelf-life prediction;
iii. food fraud and adulteration.

We decided to focus on these three areas because they are particularly tough nuts to crack for food scanners (no pun intended) – and also because of the potential societal impact. Mycotoxins and aflatoxins are very much of interest to the general public because of their potency, but current NIR food scanners fail to reach the typically low concentrations. Spoilage is relevant for people at home, so that they can estimate the age or expiration date of their product (again, very hard for infrared scanners), which could help to reduce food waste. Food fraud – finding melamine in milk or analyzing mixtures of different meat – are also out of reach for NIRS-based scanners.

We are also looking at alcoholic beverages because it's so topical, especially in countries where there are problems with fake drinks or those that contain toxic compounds.

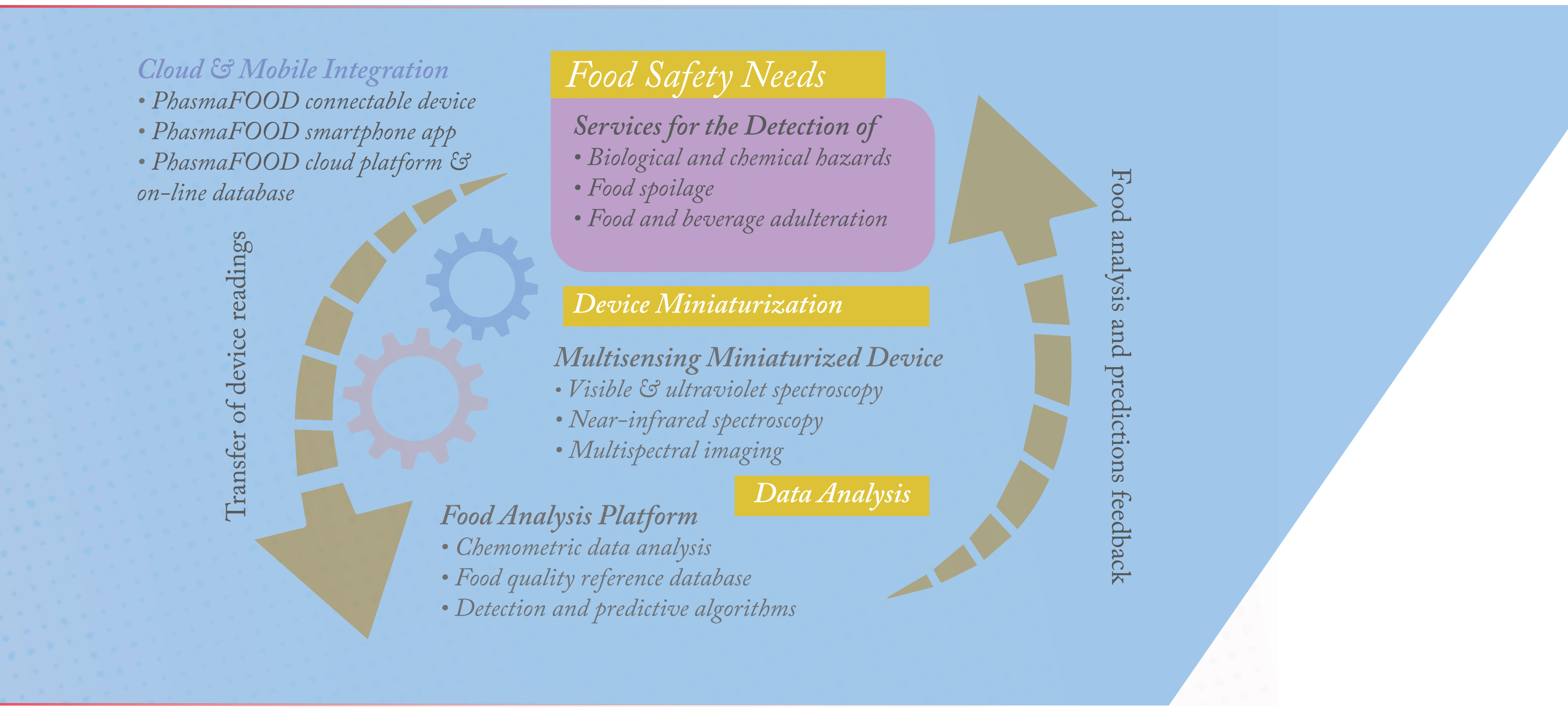
RECIPE FOR SUCCESS

Multiple partners have come together for the PhasmaFOOD project. We have the leading European IT Solutions and Services Group (INTRASOFT International), an ICT company (WINGS ICT), and cognitive networking lab VizLore, which builds apps and interactive data management systems. Then we have the hardware people from Fraunhofer IPMS, The National Research Council of Italy (CNR), the University of Rome and the Free University of Berlin, who are involved in data compression and communication between different systems. Finally, the Agricultural University of Athens and RIKILT Wageningen

University and Research are testing the sensors. Wageningen is quite well known for food research, so it's quite a logical choice!

Clearly, the consortium comprises academic and industry partners – and that is, in fact, a requirement for such EU-funded projects; if you submit a purely academic proposal, you would never get a grant. Indeed, there is close to zero fundamental research – everything is aimed at "getting it out there." We have to be at a certain technological level at the end of the project. And though the high-level view of PhasmaFOOD appears pretty straightforward – decide on objectives, make a design, build a prototype, and test it – from a project management point of view, it is highly complex, with many teams working simultaneously on different aspects. For example, we have to make measurements with sensors that are not yet mounted into a prototype, so that as soon as they are mounted, the database will be partly ready.

In PhasmaFOOD, we are going for immediate impact by making the different sensors quite defined. We want give someone who is completely untrained the capability to take a scanner anywhere, and just "point and shoot" – it's a completely new way of using a very old technique.



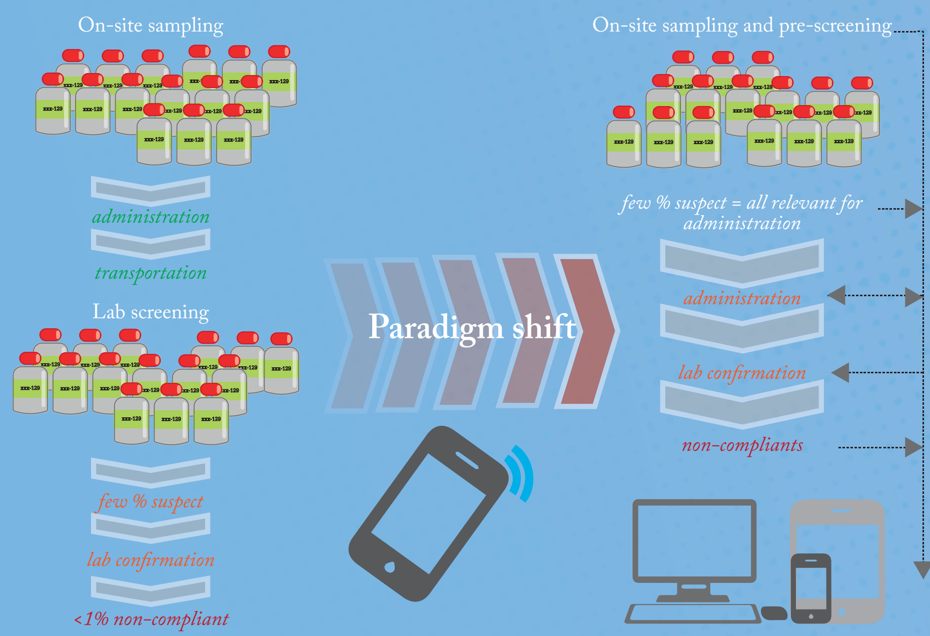
LET BATTLE COMMENCE

Ensuring food quality and safety can often be an uphill struggle. Could FoodSmartphone – a handheld bioanalytical sensing and diagnostics tool – be a more effective weapon in the fight against food fraud?

With Michel Nielen, Principal Scientist of RIKILT, professor of Analytical Chemistry at Wageningen University & Research and coordinator of the H2020 MSCA ITN project FoodSmartphone

In the field of analytical science and technology, a two-sided trend is becoming apparent. In the future, there will be an increase in on-site testing at the point of care in hospitals and GP offices, but also in the field, at farms, in retail spaces – and even at home. And that means a great deal of lab work will move to the end user. At the same time, there is also a trend towards very high-end instrumentation and orthogonal techniques that can measure both biological and physical chemical parameters in a method.

I saw the same trend in food analysis – and that's why two years ago, I applied for a European PhD training network project called FoodSmartphone, which ultimately aims to bring the tools of the routine food analysis lab to end users. I see three different and highly complementary ways of achieving that goal – but all three have different starting points and development times.



TESTING, TESTING… 1, 2, 3

The first approach is handheld food scanners, which are mainly vibrational spectroscopy- and hyperspectral imaging-driven. Such options rely on what I would call relatively low resolution spectroscopic techniques which, thanks to chemometrics, can offer significant value – particularly for onsite measurement of high-concentration food ingredients, such as moisture, fats, proteins and carbohydrates. "Nutritional value" data is also highly relevant for food traceability and food authenticity. Both the technology and the mathematics are already there. And so, what we can expect in the near future is most likely an integration of different platforms, such as hyperspectral data, combined with NIR and Raman spectroscopy data. You can do quite a lot with these technologies, but you cannot measure residues or contaminants at low levels – and that will never be within reach.

The second approach – where FoodSmartphone sits – addresses how we can drive onsite technology sensitivity down towards maximum residue limits, which means measurements at the sub-ppm level, rather than the percent level. In other words, concentration levels that are relevant to legislation, which also necessitates increased specificity and resolution. FoodSmartphone, at its core, is based on specific bio-recognition – using antibodies and other bioinspired receptors. In essence, we are bringing strip test diagnostic analysis or multiplex immunoassay equipment from the lab to the smartphone platform, and developing solutions for the food analysis field. In reality, this requires a great deal of research in areas such as surface chemistry, biorecognition, microfluidics and image data handling, so we are somewhat behind the starting point of the food scanner approach.

The third approach is also behind, but nevertheless imminent: portable mass spectrometry. In food analysis, mass spectrometry is a key technology – and the field was actually one of the early adopters. Companies are already bringing "compact" MS systems to the market, and at major conferences, you see that several venders and startup companies with the same objective. "Compact" currently means 30–40 kg, with simplified pumping systems, so the sensitivity is not world record-breaking, but may be good enough for at least a part of relevant food applications. You bring them to the field, switch them on and, within 5 or 10 minutes, they are self-tuning and calibrating. However, most of them still require a power and/or gas, so they are not "'portable" yet, but rather "transportable". The next phase is to make them truly portable – and that requires much technology development. For example, the mass range and resolution of the 908 Devices instrument is currently not good enough for food analysis requirements, but the user-friendliness of the concept is indeed a good benchmark for future developments.

BUILDING FOR SPEED

I devised the four-year FoodSmartphone project, and my partners and I applied for and obtained a 2.8 million euro Horizon 2020 grant in 2017. I am the coordinator of the entire program, which equates to about 40 percent of my time! The project has 11 dedicated PhD students working across 11 different strands, which range from biorecognition (and the development of new ligand-binding materials) to the development of smartphone-compatible detection schemes, (3D-printed) microfluidic-based sample preparation, and image data handling routines. The user interface is important, and throughout the course of the project we will identify best practices and the most promising areas. We will then apply them to specific issues, ranging from pesticides and veterinary drugs to allergens and food spoilage organisms – the real applications of interest.

The scientific challenges are multiple; first of all, the conventional immunoassay approach in the lab is far too slow. Smartphone users want an answer in seconds or minutes, and will not want to wait hours for sample preparation and incubation – so we really must find ways to speed up the process. We also need to make sure these (faster) sample preparation protocols require no training. You cannot expect people to carry out precision pipetting, or precision mixing of reagents – it must be built into a test kit.

Some aspects of the project are beyond my personal knowledge base, so selecting the best partners was critical. I selected each FoodSmartphone partner either for their track record in food analysis or for specific technological skills. For example, at Queen's University, one of the PhD students is very keen on both mathematics and image data analysis, and there is another department focused on nanoscience and nanotechnologies.

Our colleagues in Sweden are doing amazing things with 3D-printed microfluidics – and have a good track record in the engineering of printed optical parts and interfacing them with smartphones. At the end of the project, they will bring us a low-cost 3D-printed device that is capable of precise mixing and pipetting - steps normally done by a technician in a lab - at the press of a fingertip. Now that's simplified sample preparation! Of course, in food analysis, samples and extracts are dirty, so we need filtration devices. Classical filtration is time consuming, so we need well-defined and rapid filtration steps courtesy of the nanoengineering–microfiltration group at the SME Aquamarijn.

By the end of the four years, we hope to have a range of prototypes with a range of demonstrated applicability, along with commercialization plans and future areas for development for the project scientists, who will be postdocs by then. We also want to source companies who can take the project further.

> *"Smartphone users want an answer in seconds or minutes, and will not want to wait hours for sample preparation."*

SOCIAL SHARING

We must not only do good scientific work, but also train our group of PhD students with the future of food analysis in mind and make sure they obtain essential transferable skills. Each student has a personal development plan, which is partly scientific and partly focused on communication skills; for example, presenting to end users or starting their own businesses in (smartphone-based) food analysis. As well as developing proof-of-concept prototypes by the end of the project, we will have nurtured a group of people who can be the frontrunners in the development of the field. I'm very excited about the approach.

When you are designing and developing devices, it's important to communicate with the outside world – and good communication is only going to become more important in the future. For that reason, we decided that one PhD student is "on duty" each week, providing content for the FoodSmartphone blog; talking about adapting to the new environment, and what they are working on throughout the course of the project. Everybody will be able to see what researchers do and face on a daily basis.

We are also very active on Twitter, which is a first for our research. Of the many ongoing analytical science projects, so few use social media, which is a shame; after all, it can make you and your project more accessible and it also raises your profile. Ultimately, we would like to see more close communication, not only with end users from research or QC labs (who are used to finding their way through science journals), but also with a broader range of people – those who I would call non-expert lab operators and technicians. We need to get them involved. It's a major challenge, and a good first step is to be active on social media.

Excitingly, FoodSmartphone is unique. There are people working on smartphone-related diagnostic tools, and though they are exciting from an engineering or image data handling point of view, they simply do not fulfil food analysis requirements. With FoodSmartphone, we have a mixture of people with backgrounds in physics, mathematics, diagnostics and food analysis practice. By combining all our skills and knowledge into a single end-user-focused program – I think we'll be able to make a difference.