FOOD SENSORS AND TRACERS

Statement

Food is something everyone everywhere needs at all times. Food provides the necessary nutrition for growth, health and intellectual abilities of all humans. The quality, safety and origins of food directly influence our physiological and mental wellbeing. And yet despite this vital importance, the global system of production and distribution of food has not adequately served the needs of our society.

The state of technology today allows a bold rethinking of how the global food supply chains and markets could operate. A system of interconnected quality assurance sensors can reliably record the entire history of food, from farm to fork. Blockchain can protect the integrity and verifiability of sensor data. And smart contracts can enable automatic governance of food supply chains and manage commercial relationships between actors along those supply chains.

The sensing system is an interconnected system of sensors performing rapid non-invasive and non-destructive analysis. Composition/structure analysis and external environment assessment constitute the concept of Comprehensive Food Quality Assurance. The system is modular and may include both own, in-house-developed hardware or legacy hardware that is upgraded via embedded software or middleware to interact with our platform. Sensing can be mobile or stationary. The sensor system traces food and captures quality parameters about food throughout the supply chain, recording them on the blockchain.

This paper is tackling the vision of future technology about the sensing system part when combined with the digitalization world.

The Future of Food Quality Assessment: a Shift from Analytical Measurement to IoT and Digitalization

At this stage, the solution proposed by Ambrosus can be seen as a hardware part generating data about food quality and a software part digitizing and recording these data. The two parts are designed to prevent any data tampering; once a value is entered, it cannot be modified throughout the entire process. The main benefit is clearly more transparency throughout the supply chain, especially in terms of quality of foodstuff and practices. For the past 20 years, innovation in the hardware part has relied on the mindset to design smaller and smaller devices for non-invasive, non-destructive, rapid and on-site measurements. However, the deployment of such devices has remained rather limited, mainly because they are seen as adding cost with no beneficial value. Take the example of packaging embedded biosensors: they already exist in research labs, but they are not marketed because the industry only sees packaging as a passive material. On the software part, innovation lies in the fact that Blockchain is a decentralized computing system, which guarantees that the data recorded cannot be manipulated, thus creating complete transparency and deep trust into the IT system.

However, these two parts need not be seen as separated elements. Taken individually, these innovations will already heavily impact the system, but a broader, more disruptive perspective can be shaped for the future. Combining both parts – IoT sensors and Blockchain – Ambrosus becomes a whole and integrated solution, allowing to consider new designs for similar specifics. In other words, when adding the software and hardware parts, Ambrosus creates a unique integrative solution, bringing a new perspective to the food supply chain. As an example, let's say we want to authenticate the origin of a fish from the North Atlantic. Today, tissue of the fish would be sent to the lab for analysis, using laboratory methods such as Raman spectroscopy. The first step to implement our solution would be to use an on-site Raman system, derived from the laboratory system and deployed at the factory entry, for example. The fish would be analysed and the data immediately recorded onto Blockchain to assure system integrity. But we could go further and see the problematic through the lens of digitalization. With the deployment of IoT sensors, we could really change the perspective and consider the fish as a digital asset. In our example, a CCD camera can record the arrival of the fish on the boat. The fish items are then poured into containers that can be sealed, with sensors checking their integrity, and traced through RFID technology. Recording the localisation of the container, of the boat and of additional sensors such as CCD camera output and sealed integrity, in real time onto Blockchain, would assure the origin of the digital asset. Here, the digital asset is linked to the fish inside the container, consequently assuring the origin of the fish as well.

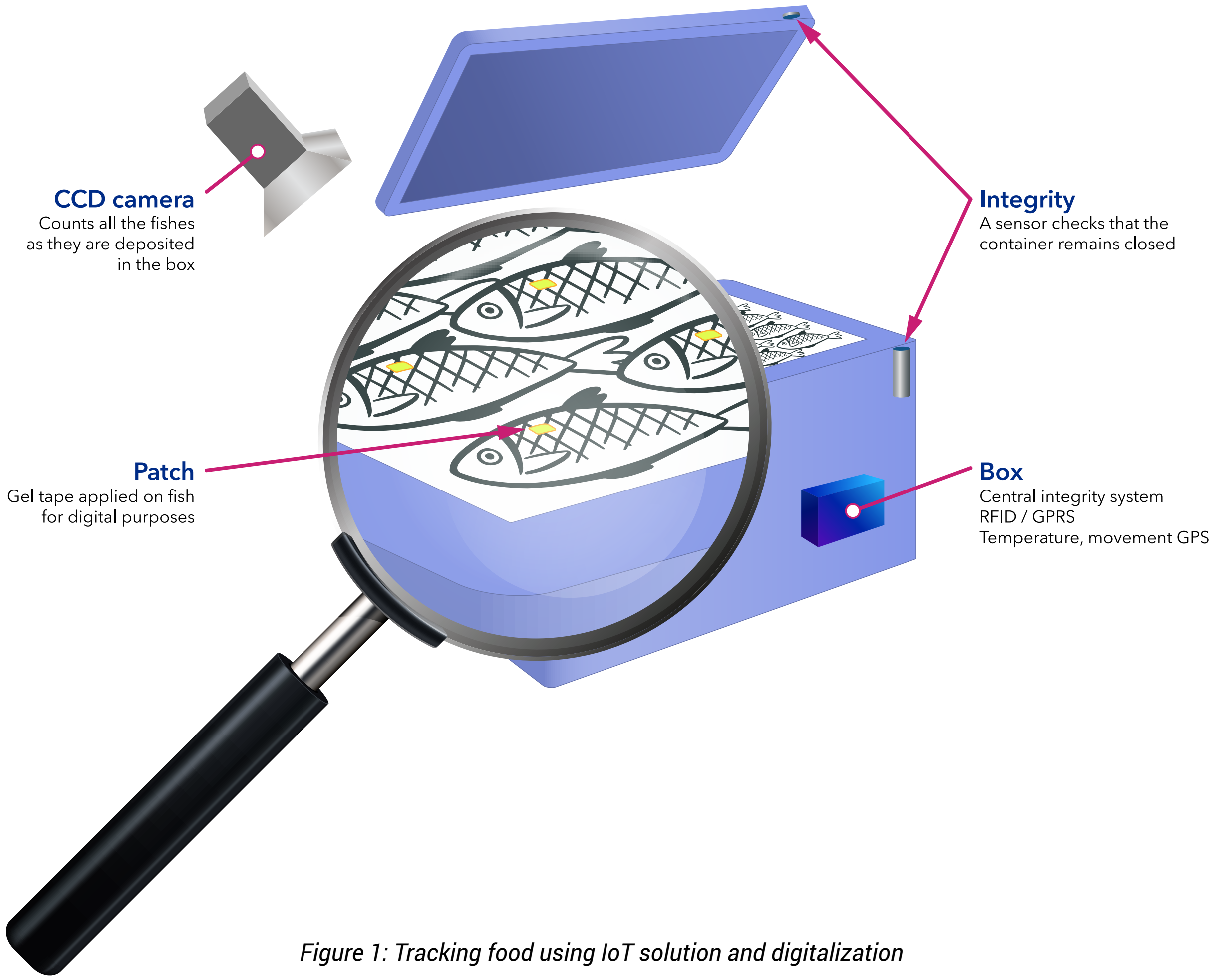

Figure 1: Tracking food using IoT solution and digitalization

Ambrosus is disrupting today's well-accepted traceability approach, where the only solution to assure origin is to bring lab technology closer to the line (to the site). Our approach is to reconsider the entire system through a digital perspective where the fish becomes a digital object that can be traced in much simpler manner. At Ambrosus, we believe on-site Raman is still a good solution, but we do not see it as the key method anymore. It becomes an auxiliary device connected to our complete sensing system.

The beauty of this solution, when considered as a whole, is that it also disrupts another well-established mindset. It is today widely accepted that the best solution to trace food commodities is to trace a unique food feature, or to insert an artificial tracer into the food item and have a checking method.

While we believe this is still a valid approach, we contemplate taking it further and consider the following development:

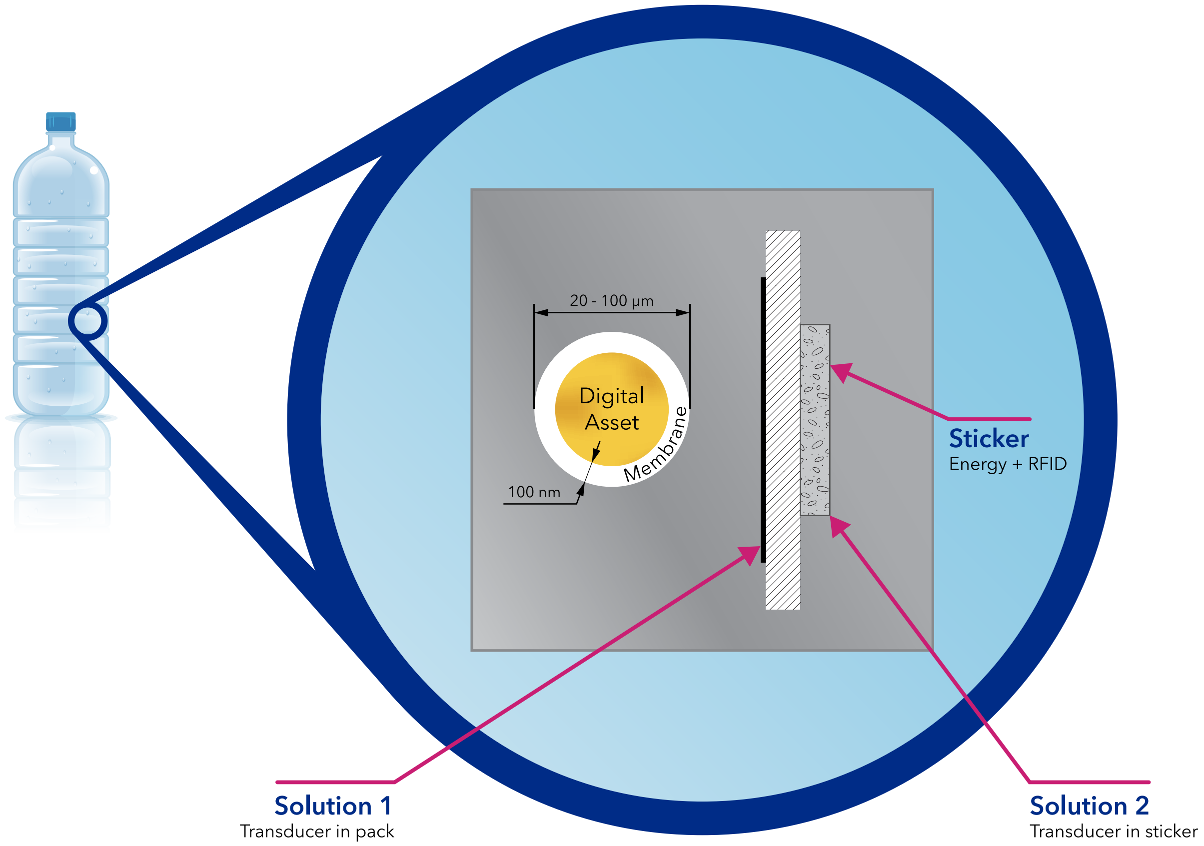

Figure 2: Food tracer solution

Conversely, our solution sees the food as an integral part of the packaging, and they both become a digital asset that can be simply traced and recorded onto Blockchain. Nowadays for example, RFID technologies trace batches of packed products without considering either individual packing, or the relationship packaging-food. If the foodstuff is manipulated, removed and replaced, it won't be detected by the actual solution in place (thus, the idea to insert a tracer). In our solution, a food-packaging relationship is established, and therefore signals delivered to the sensing system by the sensors integrated into individual packages can certify that no manipulation of the food occurred. With additional sensors, we can assure the integrity of batches, and all this data ends up in a sensing system that provides traceability and counterfeiting assurance.

This outcome relies on the quality of the sensing system composed of a multitude of sensors, including state of the art food microsensors, i.e. chemical and biosensors, integrated in the IoT domain. This new way of assessing food quality will experience in the future a gradual shift from the traditional spectroscopic analytical devices to distributed IoT sensing systems.

The sensing system can be made combining silicon microsystems (i.e. MEMS), with electronics and communication functionalities embedded in the same chip, using CMOS compatible processing, or integrated together using heterogeneous integration. Organic and Printed Electronics (OPE) can be also considered to develop sensing systems better integrated onto the products using additive manufacturing. In comparison to silicon technology, OPE offers potentially the benefits of low-cost, biocompatibility, flexibility, conformability, transparency, lightweight, and disposability for the systems.
Basically, chemical and biosensors are devices designed to inform about chemical or biological content of a given environment. A chemical/biosensor consists of:

- a chemical/biological recognition element which can be selective;
- this biological element is integrated onto a transducer to generate a measurable electrical signal proportional to the concentration of the analyte;
- a signal processing unit, which gives to the user graphical, numerical (transformed into an electrical signal for quantitative detection) or comparative (qualitative outcome such as visual colour modification) information that they shall interpret (see Fig 3).

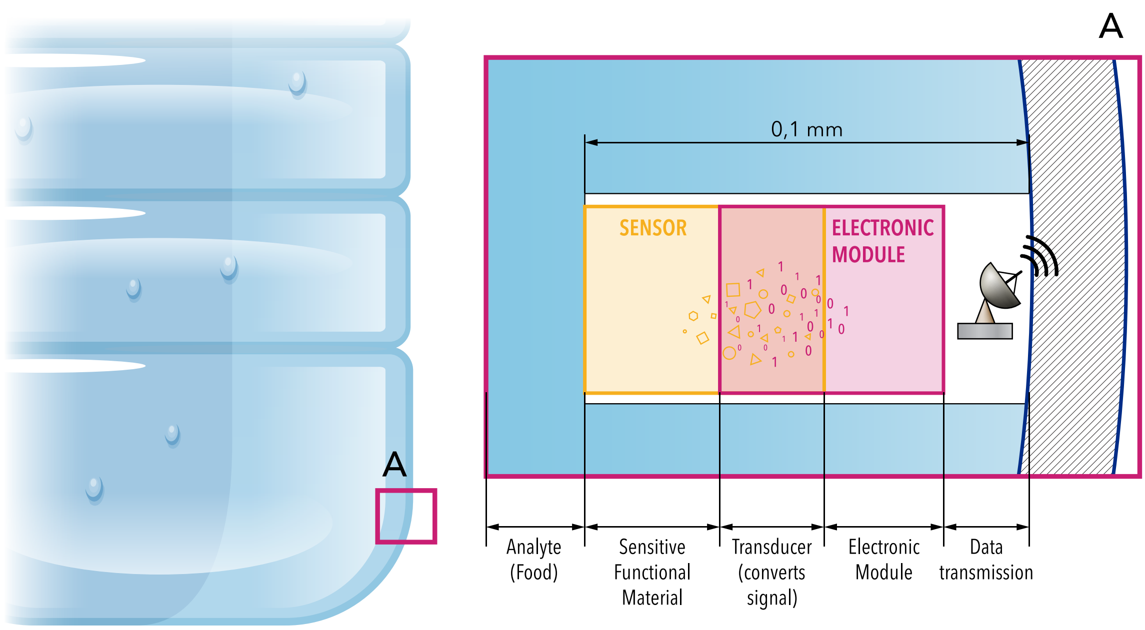

Figure 3: Biosensing technology

Different transducing principles can be implemented to convert the chemical/biological stimuli into an electrical response: notably, acoustic, electrochemical, field-effect, optical and thermal.

The recognition element can be made from many types of biological system, from antibodies, proteins and peptides to viruses, microbes, cells and tissues. The selection of the appropriate recognition element is made with respect to the analyte to be detected and the sensitivity, the selectivity, and the limit of detection to be achieved. The manufacturability of the devices and their stability and durability must also be taken into account.

The transducer is driven by an electronic chip. This chip can be replaced by fully edible food grade systems in order to allow direct contact with the food under investigation. Therefore, the electronic is embedded and can be printed directly onto the packaging.

For more complex quality controls the bio sensing system can be implemented onto a lab-on-a-chip device including other functionalities such as sample pre-treatment and microfluidics.

The technology under consideration here allows assessment of various analytes in gas, liquids and solids such as: pH, glucose, lactate, heavy metals, O_2 and CO_2, ammonia, and sulphides + amines. The sensing system can include an array of sensors for the detection of a wide range of analytes such as the major 8 food allergens.

The result here will be a unique application specific sensing systems, fully integrated, communicating wirelessly with the central gateway, able to assess items individually and monitoring the attribute throughout the entire supply chain logistics. Entire batches of product will be checked, reducing considerably the risk of poor and bad quality foodstuff.

If Ambrosus can seem to be an expensive solution, it is not when considered with the digital spirit. In our fish example above, where IoT sensors are coupled to Blockchain, we clearly demonstrated that the cost of this solution is only but a fraction of a tissue characterization through the Raman device. Not only is it much cheaper, it is also a lot more thorough as every single fish is traced, in comparison with taking one sample every so many fish to certify the origin of whole batches. In fact, our solution provides a complete control of the entire production at no extra cost in terms of instrumentation but also manpower.

In summary, it is because Ambrosus combines the innovations and inherent strengths of the hardware and the software parts that it is a disruptive solution. Naturally, as with every breakthrough, stakeholders also need to have a multidisciplinary comprehension to accept Ambrosus. Therefore, the design of the hardware part will be carried out incrementally. There is more than one solution to a specific case. We can start with already in-place sensors, then propose new monitoring systems, and finally fully embrace the digitalization concept by entirely redesigning the system into one using modern food tracers and biosensors.