



ANALYTICS AND NON-INVASIVE TECHNIQUES

General Description

Ambrosus is an end-to-end integrated solution that includes hardware, software, protocol and developer tools. It provides all the building blocks necessary to build Food Supply Chain 2.0, as well as to create an active community of developers and food enthusiasts, who in return will be building additional modules for the ecosystem, allowing it to grow and evolve on its own.

At the core of our product for food supply chains lies the concept of **Quality Assurance**, which:

- Allows complete and rapid digital transformation of quality parameters about food and its external environment into a format compatible with the Ethereum blockchain.
- Builds a robust detection system based on sensor networks to generate data and compliance certificates and store them on the blockchain.
- Permits automatization of transactions between different stakeholders in the supply chain through smart contracts, allowing automatic management of quality control and supply chain processes.

The key functional roles of the platform are:

1. To record sensor data from foodstuffs throughout the entire supply chain.
2. To ensure compliance of the food's state to regulations and client requirements.
3. To create of a Peer-2-Peer marketplace for quality-assured food.
4. To enable aggregation of purchases and delivery.
5. To integrate within existing payment and inventory systems.

Ambrosus Ecosystem package includes a comprehensive hardware support at the sensor, monitoring and data transmission level. This allows tracking of food products throughout the supply chain and assures full integrity of the readings.

The solution provides the following outputs:

- The aggregation of batches and orders of food with quality parameters will create dynamic market places and exchange platforms where buyers and sellers, or algorithms unleashed by them, will create the most efficient exchange of food batches and contracts.
- Further solutions, such as Peer-to-Peer sales from farmer cooperatives to consumers and individual food delivery through decentralised, commission-free platform will enable consumers and producers of food to capture full value of the transaction avoiding the hefty commission of today's order aggregators in the food sector.
- The incentive model of Ambers will allow community-driven development. The system will allow people to operate it through a simple and intuitive User Interface that will interact with both the blockchain and individual sensors, allowing our system to become an intersection of Blockchain and IoT.

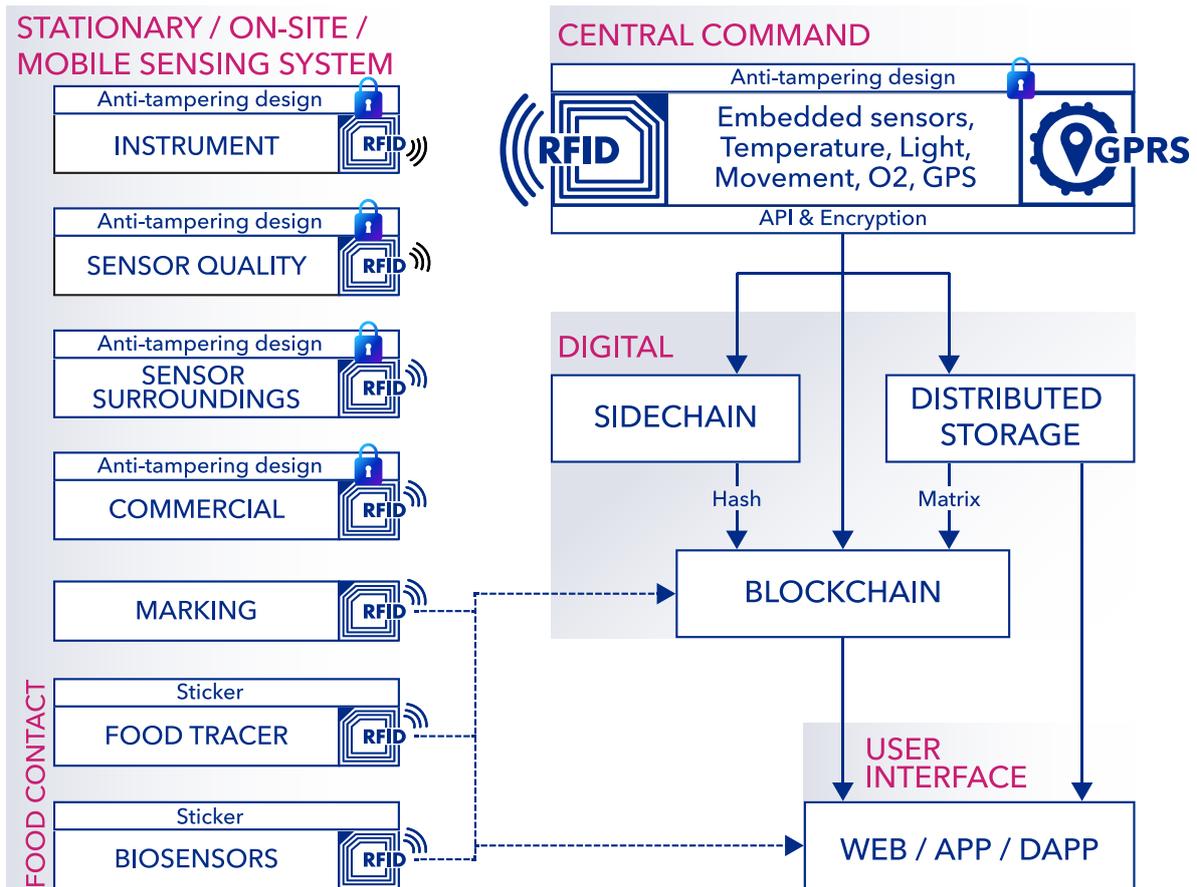


Figure 1: Overall architecture diagram

Sensing System

When food goes through the supply chain, its physico-chemical structure, composition and quality attributes vary at each stage. Therefore, a specific detection system has to be selected and adapted accordingly. At most of the stages, instead of a single system, a combination of technologies and sensors is deployed. A fully dedicated sensing system is developed and employed at each stage for each different food commodity and product.

Each solution is composed of either :

- Existing hardware and sensor infrastructure already installed in the supply chains, which we connect to Ambrosus using middleware and signal conversion techniques and/or updates to the embedded software of the systems.
- Customized hardware using either market-available sensors or in-house manufactured sensors. We have prototypes under development for sensing systems, individual sensors and monitoring devices.

Our custom-made hardware can be installed in those environments or geographical regions where there is no existing infrastructure that can collect the necessary data or perform relevant assessments of the food quality. We can thus capture both existing markets and tap into emerging markets, which are where people's awareness to food quality is increasing at the same time as their income has reached a sufficient level to demand high quality food.

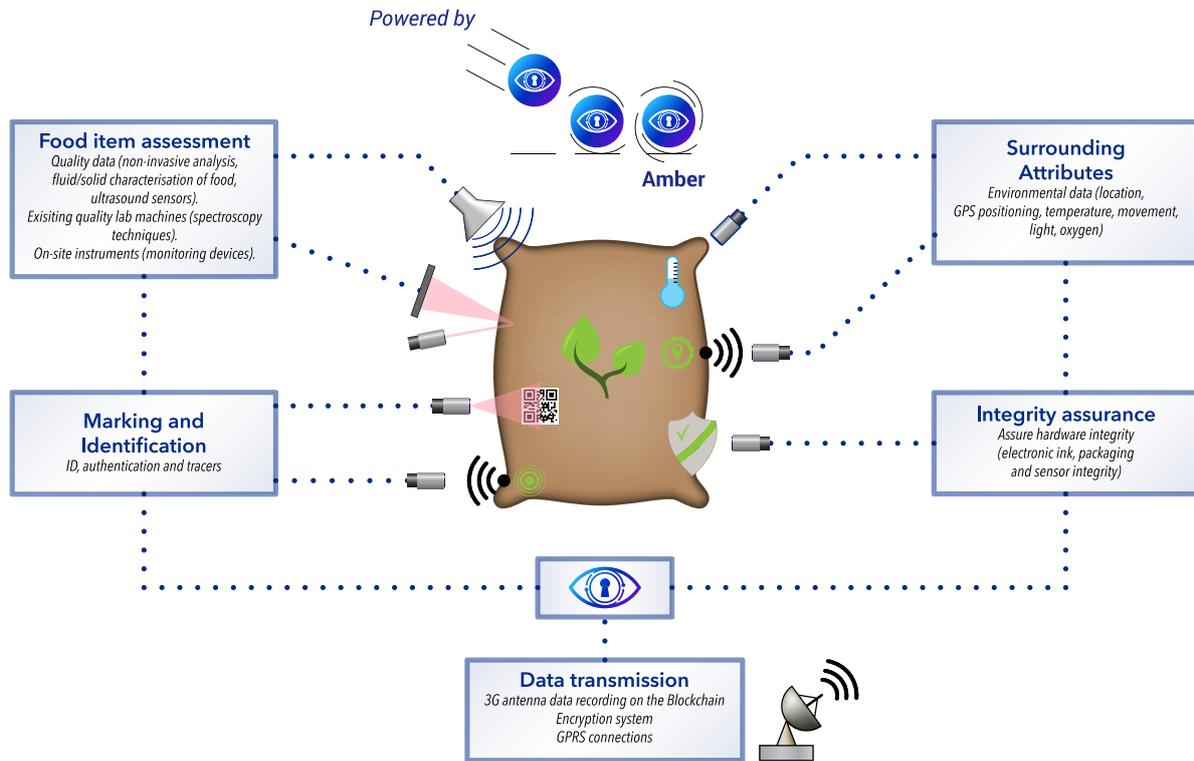


Figure 2: Design of sensing system

Detection System

The detection system is composed of mainly non-invasive sensing techniques (NIV) which we deploy throughout the supply chain at key stages where:

- The quality of the food should be assessed to assure correct rewarding.
- The properties of the surrounding food environment should be assessed to assure good handling or/and storage conditions.
- The practices and/or certificates have to be checked and digitalized in order to comply with regulations.
- The origin needs to be guaranteed and traceability to be assured in order to demonstrate transparency.
- Automatic transactions occur in order to facilitate supply chain management.
- Fraud and/or counterfeiting is likely to occur and needs to be prevented.
- Food integrity is suspected to be broken and safety is mandatory.

Non-invasive techniques (NIV)

Non-invasive food assurance is obviously based on non-invasive techniques, as shown in the following illustration (fig. 3). Most of the NIV techniques are based on physical methods of analysis, with the exception of biosensors.

Optical, electrical, acoustical, nuclear and biosensor technologies are employed and implemented at key stages of the supply chain, which are identified by using forecasting tools. Their purpose is to prevent wrongful data manipulations, to digitalize certificates and to automatize processes.

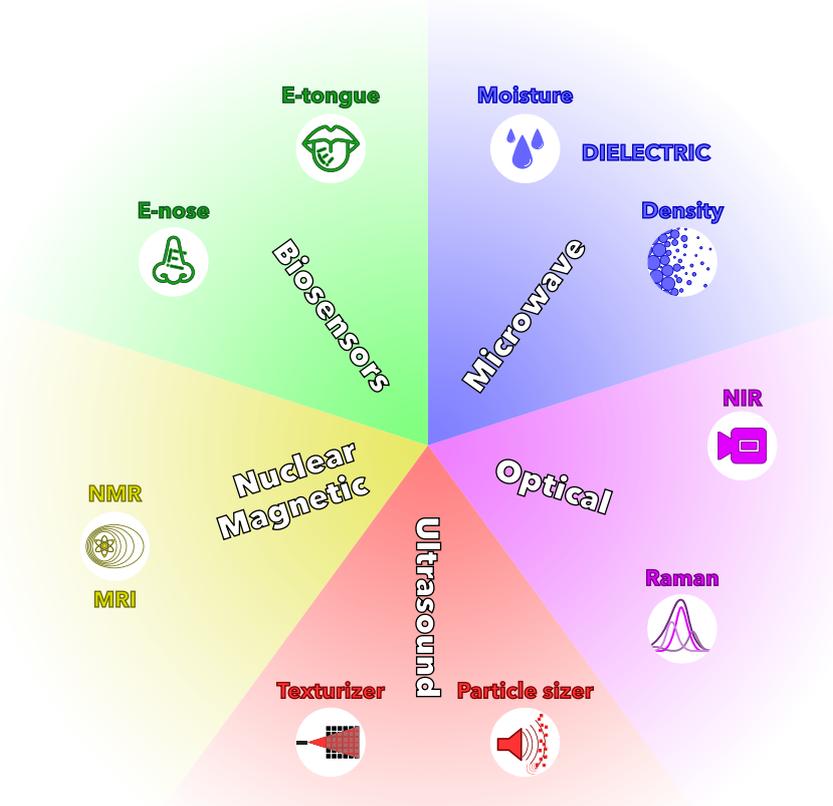


Figure 3: Non-invasive sensing techniques in food quality assurance

Here is a non-exhaustive list of techniques that are considered in our lab:

- **Optical system**, such as machine vision from Imperx using a CCD camera combined to the Halcon software, provides external information such as color, shape, size, and the absence of surface defects of food products.
- **Near Infrared Spectroscopy**, such as the LabSpec 4 from ASD in the US, analyzes the physical-chemical parameters of food, such as freshness, water content, soluble solid contents, acidity or firmness. Allergens can also be detected by the TellSpec enterprise scanner on-site measuring device.
- **Raman spectroscopy**, such as the Brucker BRAVO portable system, authenticates many types of food. The application of Raman technology has been successfully implemented to assure the quality of dairy food, meat, fish, egg, vegetables, oil, sugar as well as the identification of bacteria of agro-alimentary interest.
- **Microwave technique**, such as the Intelscan from TEWS that characterizes the dielectric properties, assesses moisture and density of food on-line.
- **Ultrasound** system in-house developed [1-4] can provide internal quality information, such as firmness and crispness, taste, aroma, and absence of internal defects. The technology allows fat crystals characterization in raw materials, determination of shelf-life and to size particles in liquids on-line.
- **Electronic nose and tongue** from Airsense Analytics can give quality attributes such as freshness, nutritional value and presence of chemical residues. This field is in rapid development and non-invasive systems are foreseen.
- **Nuclear magnetic** is sensitive to the existence of mobile water, oil, and sugar, which are major components of agricultural materials. Therefore, owing to its non-invasive nature, NMR has a high potential for use in internal-quality evaluation. NMR spectroscopy such as the CEM fat analyser has been successfully used for detection of sugars, fats and acids.

Spectroscopic based databases and associated chemometric models when necessary for the above described techniques are generated for use on user friendly rapid in-field instrumentation.

Physical sensors can provide information about the quality of the food and its storage. For example, the temperature may be measured and stored over the time in order to provide a thermal history of the food and its packaging during the transportation and storing processes, and all along the production and delivery chain. Photodiodes can be used to store data about the light exposition of the food, which also has an impact on food degradation in case of some meals. Chemical sensors can also provide several information about the quality of the food. For example, they can measure the pH level over time, which is definitely related to food quality as well. Furthermore, other chemical sensors can also provide information about allergens.

In addition, and where appropriate, immunological based methods, enzymatic techniques, DNA and protein assays will also be used to assess food. Surrounding attributes such as temperature, light exposure, humidity, movement and oxygen will be recorded. These parameters are key to evaluate good practices. Modules such as the K-2 from Kizzy tracking integrate surroundings assessment sensors. The K-2 is under development to embed additional sensors and allow connection to NIV systems. This system is able to assure data integrity and also to transmit data to the appropriate blockchain module. We will start deployment of the solution using this K-2 module before manufacturing our own system. Finally, NIV methods already in place and any other sensor technologies can also be integrated into the sensing network.

Marking technologies will also complete the sensing system. The Markem-Imaje in-field printers are used to mark, assess and identify each item. In addition, we aim to develop transparent QR codes to be printed directly on food.

Packaging traceability solutions (RFID tags from ID Tronic or QR codes), as well as of food tracers if appropriate, will be inserted to improve traceability performance and to permit following individual products down the chain to the consumer.

The long-term vision is to build 5 research programs with which we aim to include the following non-invasive foodstuff assessment technologies into our value proposal. Developed in conjunction with the EPFL food-tech ecosystem, those technologies are:

- Biosensors integrated into packaging,
- Biosensors with energy and transmission system included in a sticker embedded into the packaging's external stretch films,
- Nanosensors, electronic ink and embedded thin film sensors having colour visualization systems or/and quantitative outputs,
- Embedded biocompatible ultrasonic sensors for smart packaging,
- Printed microassays for bacteria detection,
- Bio-optical sensors for spoilage detection,
- Temperature sensors integrated into the packaging,
- Humidity measurement and leakage determination.

New ways of printing and depositing gel patches on food is also foreseen, whereas development of transparent QR codes is already under development. Biosensors will interface with analytes to determine allergens, pesticides, phthalates, fatty acids, etc. And last but not least, we will consider new NIV approaches to assess texture and structure of ingredients as well as techniques to quantify taste and on-site measurement.

Intellectual properties are actually under consideration at the NIV level as well as for the biosensors systems.

The use of non-invasive and on-site technologies proposed by Ambrosus has multiple advantages over the more classical, static laboratory methods: the system is non-invasive, non-destructive, rapid and in most cases requires no consumables (no chemical products are necessary to perform measurement). Furthermore, Ambrosus sensor systems are fully automatic, i.e. no additional method needs to be developed by the manufacturers and no skilled technicians is required to operate it. This allows even the smallest of businesses to use these devices at no extra cost or expertise. Ambrosus sensor systems only require a one-time calibration and validation procedure, which can be done remotely and is included into the service package.

-
- [1] Characterization of reconstituted milk powder by ultrasound spectroscopy (2006); Meyer S, Povey MJW, Rajendram VS; *Journal of food quality* 29(4) pp 405-418
 - [2] Non-contact evaluation of milk-based products using air-coupled ultrasound (2006) Meyer S, Hindle S, Sandoz JP, Gan TH, Hutchins DA; *Measurement science and technology* 17(7) pp1838
 - [3] A comparative study of ultrasound and laser light diffraction techniques for particle size determination in dairy beverages (2005); Meyer S, Rajendram VS, Povey MJW, Goodenough TIJ, Berrut S, Pinfield VJ; *Measurement Science and Technology* 17(2) pp 289
 - [4] Development of a multi frequency pulse diagnostic ultrasound device (2005); Goodenough TIJ, Rajendram VS, Meyer S, Pretre D; *Ultrasonics* 43(3) pp165-171
-