DELIVERABLE 3.1.2

FOOD MICRO SYSTEMS

FINAL REPORT OF INDUSTRIALS' NEEDS, DEMANDS AND CONSTRAINTS

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SEVENTH FRAMEWORK PROGRAMME

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FoodMicroSystems aims at initiating the implementation of microsystems & smart miniaturised systems in the food sector by improving cooperation between suppliers and users of microsystems for food/beverage quality and safety.

The project runs from September 2011 to November 2013, it involves nine partners and is coordinated by ACTIA (Association de Coordination Technique pour l'Industrie Agro-Alimentaire, France). More information on the situation of the research concerning Microsystems in the food sector[1][2][3] and on the consumers' perception[4] & acceptance[5] can be found at http://www.foodmicrosystems.eu

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[1] http://www.foodmicrosystems.eu/wp-content/uploads/D1-2_without-email.pdf
[2] http://www.foodmicrosystems.eu/wp-content/uploads/D1-3_without-email.pdf
[3] http://www.foodmicrosystems.eu/wp-content/uploads/Foodmicrosystems-D2-1.pdf
[4] http://www.foodmicrosystems.eu/wp-content/uploads/FoodMicroSystems-D3-2-1.pdf
[5] http://www.foodmicrosystems.eu/wp-content/uploads/FoodMicroSystems-D3-2-2.pdf

Content

Executive summary: key findings from the report

1) With more than 270.000 companies, the food sector represents **a significant market** for developers of microsystems solutions. It includes a limited number of large companies controlling many production sites and a high number of small producers supplied by a very large number of farmers (e.g. 1 million farms delivering milk to 5000 processors in the EU).
2) One of the key drivers for implementing microsystems in the food sector is **food safety**: the food industry needs solutions that guarantee that the food is safe for the consumers. There is a demand for in-line solutions (continuous measurement) as well as for portable and easy-to-use devices.
3) Another key driver is related to **food quality**: a better monitoring of the quality parameters of the raw materials, of materials during processing and of the final products is needed to optimise the processes. The demand is mostly for solutions allowing continuous and simultaneous measurements of several parameters. Portable devices for in-situ measurements are also in demand.
4) The recent "horse meat" crisis also reveals that there is a market for solutions allowing **authentication** (solutions to detect the origin of the food products), **traceability** and detection of **fraud and adulteration**.
5) Solutions to **optimise the water and energy consumption** are needed to decrease the impact of the industry on the environment and to reduce the production costs. Tools allowing the **optimisation of cleaning operations** are particularly in demand.
6) **Intelligent packaging** that can monitor the deterioration of food products and increase their shelf-life are also interesting innovations.
7) Overall, there is a strong demand for **process control applications**. In-line, on-line and at-line measurement solutions will help the industry to address the four key challenges of the sector (safety, quality, sustainability and efficiency). These solutions should be embedded in the process management systems of the industry to allow actions (measurement is not enough, they need to be utilised).
8) The **main technological constraints** are related to (i) the robustness of the devices (ii) the reliability of the measures (iii) the compatibility with food processes and (iv) the time to process information. The sampling strategy (how many measures, when, where etc.) can also be a challenge.
9) There are important **organisational constraints** for developers of microsystems solutions interested to enter the food industry market. A very good knowledge of the sector and of its practices is needed from the conception phases so that the solutions proposed are properly embedded in the management practices of the food producers. For this, there is a need for systematic exchange of knowledge and information between the microsystem solution providers and the food businesses and innovation supporting organisations and government programmes should facilitate this trans-disciplinary approach.

1 Introduction

This *FoodMicroSystem* report describes the food industry demand for microsystems. It is designed for companies and research organisations developing microsystems with the view to help them to better understand how the food industry can represent an attractive market for future microsystems applications. It gathers the views expressed by the food industry in a study implemented in 2012 and 2013 in several EU countries: the report provides information on the needs from the food sector and discusses the constraints for implementing microsystems in the food industry.

Microsystems are components built with micro and nano technologies. Microsystem devices and smart miniaturised systems often use microsensors, electronics, signal processing, micro-actuators and microfluidics. In the food industry, they are mainly used in systems that provide information on the food products, but could also be used to improve the process, and change or preserve the properties of the products. They can measure efficiency with in situ, non-invasive, faster and automatic sensors using fewer samples and reagents, but also less energy.

The food industry is the largest European manufacturing sector with more than 270.000 companies providing employments to more than 4 million persons and an annual turnover of 956 billion Euro[6].

The food industry is characterised by large volumes and small profit margins. Depending on the specific type of food chain, the market can be very concentrated with a few dominant players (for example in the dairy sector, the top 5 players represents 30% of the market share) or scattered in a very high number of small players like in the wine sector. Besides the powerful major players like *Unilever, Nestlé, Kraft Foods or Danone* who have specialists for different tasks, the food sector also comprises many small and medium enterprises (SME), including many family businesses, often comprising of only a few employees responsible for all tasks in a company, including production, quality control, innovation and finances. If needed these smaller firms outsource parts of their operations to external companies: for example many food quality and safety controls can be sub-contracted to external laboratories. Both large and small companies relies on a great extent on specialised companies for the design and the construction of their productions chains. SMEs providing equipment also play a major role by supplying sensors, measurement devices or process control systems.

The food market includes many traditional processes involved in authentic and traditional production, but also includes highly industrialised automatized production. Food production includes many chemical and biological products and productions steps that may introduce pollutions, contamination or spoilage into the process. This means that cleaning, sterilising of production and equipment are

[6] http://www.fooddrinkeurope.eu/uploads/publications_documents/temp_file_Summary_FDE_datatrends_page_par_page1.pdf

essential steps in food production and process equipment should be able to withstand rough treatment and abrasive cleaning.

Food industry itself however is not a single industry but is composed of many different production systems that have only partial overlap.

Issues of importance for dairy such as continuous flow, extended shelf life, fermentation, extraction of high value proteins are of less importance for meat production, where hygiene, foreign bodies like bone fragments, cross contamination and bacterial contamination present important challenge.

Other products like wine or beer, have relatively higher added value and may gain even higher value with aging- high investment in time and resources that cannot be afforded to be lost, but require high level quality of control, or lose a whole batch.

Fruits and vegetables which continue to ripen and spoil after production and shelving; the optimum quality is reached after packaging. Logistics in moving about vulnerable product over large distances is particularly tricky for fruits and vegetables.

Finally packaging industry is an important industry in all food products, but has its own typicalities. Packaging is important to enhance shelf life and product quality, protect products during transport and for presenting information to the consumer and chain actors. Packaging however, as a food contact material requires very strict quality control in and out of itself.

Together dairy, meat, fruits and vegetables and beverages (wine) represent a fairly comprehensive overview of both the food industry in volume and the scope of problems and issues encountered in the production process. The report provides a detailed analysis of the needs and constraints for implementing microsystems in these four sectors.

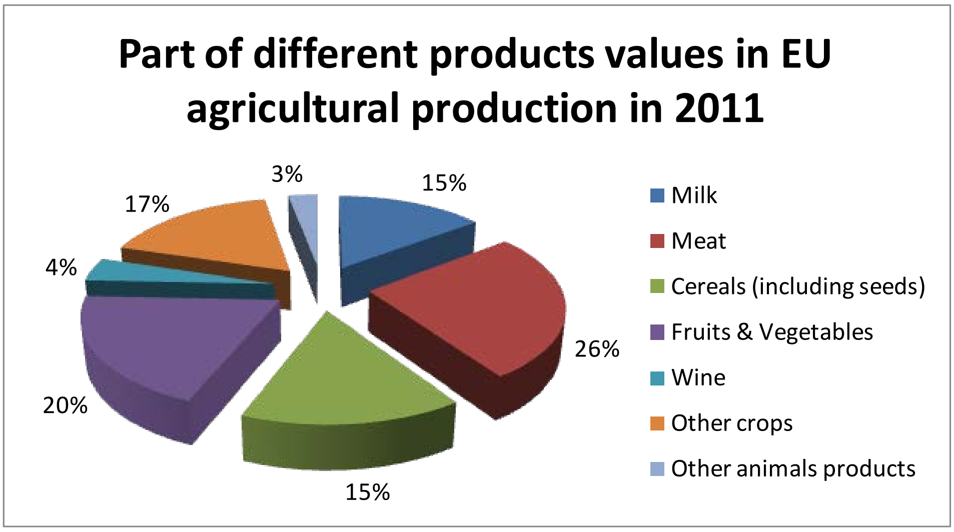


Figure 1 Part of different products values in EU agricultural production in 2011

2 Methodology

The potential applications of microsystems in the selected food chains presented in this report have been identified through (1) preparatory work, (2) workshops and interviews with food companies, (3) web-consultation with other companies. The analysis is carried out in five representatives EU countries: Estonia, France, Germany, the Netherlands and Spain.

The methodology of the preparatory work has analogies with a HACCP methodology. HACCP (Hazard Analysis at Critical Control Points) is a methodology utilised in the food sector to guarantee food safety: it evaluates the danger (hazard) that can possibly occur during the production, identifies the steps at which these dangers can appear (critical points) and establishes measures to control these hazards. It is based on a detailed analysis of each "operation unit" of the production. A similar approach has been used but, instead of hazards, the critical points identified are points for which application of microsystems is interesting and can significantly improve the current situation.

The preparatory work consisted of establishing, for each food chain, diagrams of the production processes. For each food chain selected, one or several tables have been prepared indicating the critical points identified as relevant for a potential solution or improvement with the contribution of microsystems.

As an example, for the dairy sector the following table has been set up identifying the critical points where Microsystems can provide a solution (Contribution of ACTILAIT).

<table>
<tr><td colspan="5">Synthesis table of technological needs for Microsystems development in the different activity of the dairy sector:</td></tr>
<tr><th>Dairy sector activities</th><th>Milk collection, transport, storage</th><th>Treatment of milk</th><th>Transformation</th><th>Conditioning</th></tr>
<tr><td rowspan="9">Thematics or Technologies</td><td></td><td>Process optimization
Ability indicator of milk to the growth of lactic acid bacteria</td><td>Process optimization
Ability indicator of milk to the clotting
Control online of pH kinetic (acidification during cheesemaking, deacidification during ripening)
Control online of the drainage in curd and cheeses
Control online of clotting properties (firmness, rate of firming)
Control of the maturity of cheeses during the ripening
Control of the opening characteristics (hard cheeses)</td><td>Intelligent packaging
Leak indicator (ripening under film, vacuum packaging)
Cold logistics: Time/Temperature indicator</td></tr>
<tr><td colspan="4">Analyzing</td></tr>
<tr><td colspan="4">Online indicative measurement of microbiological quality of products (Pathogens, Total Flora, Bacteriophage)</td></tr>
<tr><td colspan="2">Measure/evaluation of the lipolysis in milk</td><td></td><td></td></tr>
<tr><td>Control of residual antibiotics on the farm</td><td>Measure of whey proteins denatured</td><td>Measure/evaluation of the fermentation activities (lactates, volatile fatty acids)
Measure/evaluation of the mineralization (soluble and colloidal calcium)
Measure of the rate of salt and its distribution
Measure/evaluation of the proteolysis in cheese</td><td></td></tr>
<tr><td colspan="4">Cleaning
Online indicative measurement of cleaning and/or disinfection efficiency
Online indicative measurement of the presence of biofilms</td></tr>
<tr><td colspan="4">Traceability</td></tr>
<tr><td colspan="4">Miniaturized systems for products tracking along the production lines (Ex : RFID chips)</td></tr>
<tr><td colspan="2">Miniaturized systems for tracking the thermal history of milk</td><td></td><td></td></tr>
</table>

Seven workshops linking the food chain related demands and possible micro and nanotechnology systems were organised. Two kinds of programmes have been used. Either the demands were presented in plenary cessions and next subgroups were formed to discuss a demand (demands not linked, large audience); or the demands were presented one after the other and discussions were held after each presentation with all the participants (related demands, small audience). Findings from the workshops have been complemented by interviews of food and equipment companies. In total, around 100 food companies from Estonia, France, Germany, Spain and the Netherlands have been consulted.

All these findings have been summarized in a draft report that has been published on FoodMicrosystems website and sent by email to stakeholders with a couple of questions to ask for additional information.

Table1: Participant list in the web consultation

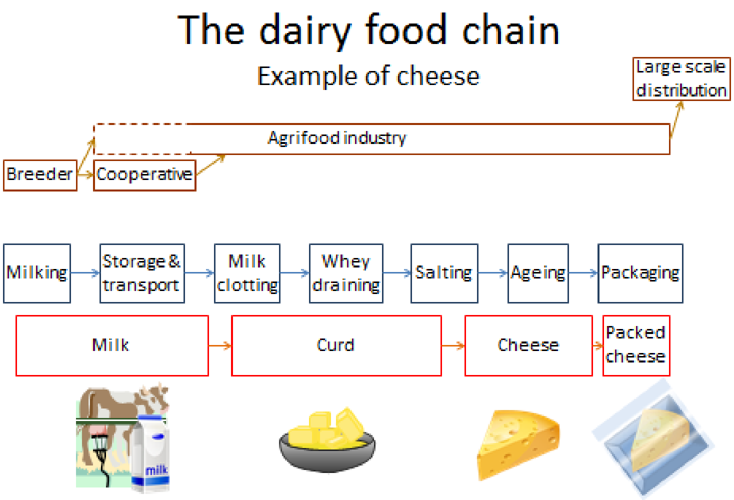
Organisation	Person	Country
Center of Pharmaceutical Studies University of Coimbra	Nuno Mendonça	Portugal
Bucher Vaslin S.A	Pascale Noilet	France
prelonic	Friedrich Eibensteiner	Austria
fbk	Alessia Mortari	Italy
LCC Engineering & Trading GmbH - Koldsteril AG	Willi Glettig	Switzerland
Oséo Innovation	Ariane Voyatzakis	France
Wageningen University	Eisner-Schadler Verena	The Netherlands
Department of Life Sciences, University of Parma, Parma, Italy and Technopole SITEIA.PARMA	Nelson Marmiroli	Italy
eii.uva	Mª Luz Rodríguez Méndez	Spain
Rakvere Lihakombinaat AS	Maarek Jõhve	Estonia
Wageningen University	Togtema, Arnoud	The Netherlands
CTCPA	Alain MIMOUNI	France
ANIA	GORGA Françoise	France
CSIC	Antonio A. Alonso	Spain
Wageningen University	Karin Schroen	The Netherlands
UNIVERSIDAD DE VIGO	ELISA GONZÁLEZ-ROMERO	Spain
campdenkht	András Sebők	Hungary
Nestlé	Richard Stadler	Switzerlan
imel.demokritos	Eleni Makarona	Greece
ikerlan	Jesús Miguel Ruano	Spain

3 Results

3.1 Dairy sector

The dairy sector is one of the most important food market in Europe: milk is one of the first agricultural product in the EU in terms of value at approximately 15 % of the total agricultural output; it represents 50 billion euro. The EU is a major player in the world dairy market, it represents around 20% of the world wide milk production and account for 25% of the world dairy trade. The main producers are Germany, France, the United Kingdom, the Netherlands, Italy and Poland: they represent more than 70% of the EU production.

The dairy sector is characterised by a high level of concentration: the first five key players (*Danone, Unilever, Friesland Campina, Nestlé, Arla*) represent more than 30% of the European dairy market. Most of the dairy companies collect, process and commercialise milk products. They engage with long-terms partnerships with dairy farms. In the EU-27, there are more than one million farmers supplying annually close to 150 million tonnes of milk to around 5.000 dairy processors (55% of which are SMEs)[7].



3.1.1 Needs and demands

3.1.1.1 Safety and hygien

Dairy industrials are looking for advanced **contamination detection methods** as tools to detect and assess more **quickly** any contamination incidents or threats. To protect even more products from the risk of contamination, improvement in **cleaning operations** can be made thanks to microsystems applications.

7 http://ec.europa.eu/agriculture/eval/reports/dairy/

a. Fast microbiological analysis

Under some signs of quality, the specification indicates that the maximum time between the oldest collected milking and renneting is 24 hours (protected designation of origin Mont d'Or, Morbier, Comté). This short time does not currently allow having the results of microbiological detection of pathogenic bacteria (e.g. Listeria, Salmonella) before the processing of milk.

The main need for these traditional industries is thus to have a means of **detecting** various pathogens (Listeria, Salmonella, STEC) that can deliver an answer within a **short time** (less than 12 hours). Dairy industries are also interested to have tools for **rapid or online detection** of bacteriophages in milk and whey. **Control online** of the milk could also be very interesting.

b. Portable devices

Portable device for in-situ and quick **diagnostic and identification** tools for the **animal diseases** is an important demand. Microsystems could provide quick solutions in case of outbreak of a new disease or a new strand.
Detection of animal diseases in e.g. faeces, in-line monitoring of micro-organisms with the use of microsieves (Innosieve), are of interest for the sector. Farmers do not have PCR equipment. They need a more user friendly test tool, which can be easily used on farms (like the at-home-pregnancy test) such as a specific transportable PCR system.

Microsystems could also **distinguish the type of organism** which is causing the disease to know which specific antibiotic must be used. Detection of specific compounds in the milk can also be of interest for the sector. For instance to distinguish between "Weidemelk" (a Dutch word meaning milk from cows that eat grass in a pasture) and ordinary milk from cows in a barn fed with hay and concentrate.

c. Cleaning operations

Performance monitoring and optimization of units of Cleaning in Place (CIP) would allow a significant gain in productivity. Presently, the length of cleaning cycles is based on empirical means. Dairy companies need to have a **reliable means of monitoring the effectiveness of their cleaning** so they can finely control cleaning operations and with full knowledge of the facts in keeping with microbiological hazards.

Currently, checks are performed to monitor the effectiveness of cleaning: upstream controls to check the good application of instructions for use of detergents to bring a good efficiency to cleaning products (detergent concentration, exposure time and temperature). All these tests give an idea of the fouling and of the level of bio-contamination at a given time but they are not sufficient to control the process of cleaning and disinfections. This evaluation is only possible through the use of online sensors related to the automation which drives the cleaning station. **Fouling problems** in microchips have been solved; it would be interesting to now convert this solution to large scale installations currently used in the food industry. Surface modification could provide solutions, but the question is if these modifications are stable under treatments necessary to e.g. clean the machines.

Alongside the cleaning efficiency, a need for **controls on the persistence of cleaning products** has been identified. Indeed they can pollute the raw material and cause problems in the lactic fermentation necessary for the fabrication of many dairy products.

3.1.1.2 Quality control

The dairy industry always looks for possibility to improve its productivity. For this purpose, industrials needs to better **control specific processing steps** of cheese making such as milk clotting, dry matter, whey protein and denaturation rate or the opening characteristics of cheeses. For this, non-intrusive, cheap and fast sensors measuring new parameters are needed.

a. Milk clotting

To achieve a maximum yield of cheese and the best quality of cheese, the cheesemaker is looking for a precise determination in **continuous of the firmness of the coagulum** for optimal cutting. Moreover, changes in equipment (closed tanks) and labour legislation (safety), the increase of the size of the cheese plant and the increasing importance of automation explain the need of an **objective instrumental method online and in real-time** for the **monitoring of clotting characteristics**.

b. Dry matter

There is no method to measure the **draining of whey in vat**. However this parameter is critical to determine the time of moulding the curd. As for clotting characteristics, changes in equipment and the increasing importance of automation make the need for a measure of dry matter online and in real time even more relevant.

c. Whey protein and denaturation rate

To increase yields, dairy industries apply to milk important heat treatments to denature the whey proteins which can thus be recovered in the curd and better valued. The **monitoring of the denaturation rate** would improve regularity of yields and decrease the standard deviations of weight. This will allow a lower average weight of the cheese with an increase in profitability.

d. Opening characteristics

An objective method to determine the **opening characteristics of cheeses** would allow better management of ripening cycles (e.g. out of hot room, temperature, humidity, etc.).

3.1.1.3 Other issues

a. Traceability

Industrials are looking for solutions to trace antibiotics and hormones in milk and to ensure that the food purchased is not adulterated.

b. Surface status and monitoring of materials ageing

On this topic, three themes were identified: Qualification and quantification of **interactions between materials and cleaning products; sensitivity of surfaces to the development of biofilms**; and **monitoring of the mechanical properties of a material** (for example the porosity of mould and the capacity to evacuate the whey).

c. New production device - micro sieves

milk filtered by micro sieves without heat treatment: enzymes are still active (no thermal inactivation).

Actual micro sieves deliver a log 7 reduction, which is inferior to sterilisation, but better than pasteurisation. Therefore, there is a great opportunity for improvement and development for these microsystems by increasing the log reduction. With this treatment, milk can be stored uncooled, which is a relevant advantage for the consumer. Added value for the consumers must be transparent, because if they see a benefit, the industry will invest. **Replacing sterilisation** will avoid heat treatment that influences certain constituents of the product which could change the flavour for example. Nanomembranes could be a new way to **fractionate whey proteins**, to add value to the whey (lactoferrin) and to separate certain components (specific proteins) from the main stream. These ones could add value to high end products (energy and sport products, medical food, healthy products, etc.).

3.1.2 Constraints for implementing microsystems

Dairy industry is a sector of small margins and the **costs of microsystems** can represent a barrier to their implementation. To decrease the costs, the numbers of devices (e.g. microsieves) must be high but one major difficulty is to scale up the device at commercial level.

Dairy industrials need to critically evaluate the financial impact of the new technology compared with the one currently used (capex/opex). Energy (=cost) saving could trigger the use of new technologies. Calculations for these cases show that a technology has a financial margin to fit in of 0,03 ct/l. In general, dairy industries are ready to invest if the return on investment is less than 3 years.

On a technical point of view, some devices still require specific equipments (like PCR), so they first need to be **more user-friendly or automatic** before being available for farmers to test their milk. For applications of milk sterilisation with microsieves, a better log reduction is necessary to remove all active bacterias.

For the adoption of microfluidic methods it is necessary to create new products that can only be made through these methods or to realize significant improvements of existing methods (reduction of emulsifiers = E-numbers).

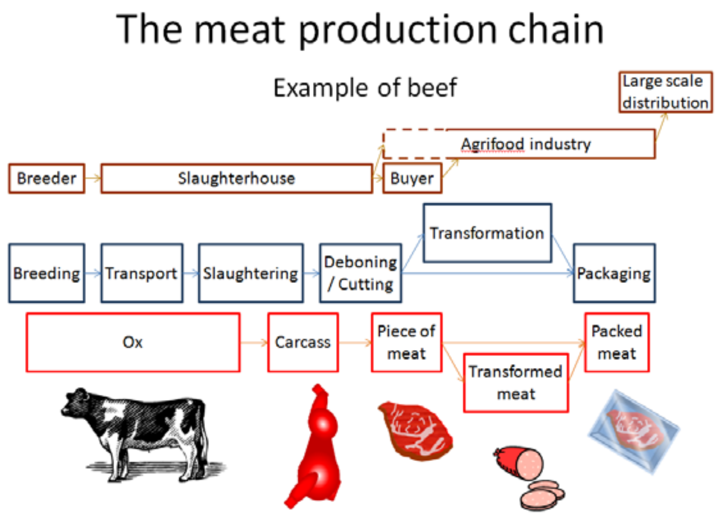
Overall, systems must be food grade (they need to be safe, materials in contact with the food must be authorised, breakage or leakage need to be prevented), integrated into the process and able communicate with automatisms in order to control the process.
For many technologists, one important constraint to meet concerns **cleaning issues**. Technologies must be fixed and easily compatible with the cleaning techniques used. This concept is important because it is unthinkable for the dairy industry to integrate a system too fragile to withstand cleaning procedures or that can be a potential point of contamination in the process. It is important to look at fouling of the devices and how they can be cleaned in an industrial setting. Finally the possibility of disassembling a device, such as a sensor, before cleaning is rejected for reasons of practicality and cost in staff time.

3.2 Meat sector

With an annual output above 100 billion euros representing 27% of the total agricultural output in 2011, the animal production is the largest agricultural production in the EU. Pig is the largest market (37% of the EU meat production) followed by cattle (32%), poultry (21%) and sheep and goats (6%)[8]. Europe accounts for 20% of the world pig-meat production, the main producers being Germany, Spain, France and Poland followed by Denmark, Italy and the Netherlands (85% of the EU production). For beef, France, the UK and Germany are the most important market (45% of the total EU production). The main producers of poultry meat are France, the UK, Germany, Spain, Poland and Italy (70% of the production) while the sheep and goat production is concentrated in the UK, Spain and Greece (also 70% of the production).

The meat sector is less concentrated than the dairy sector but it is still a concentrated market: the top 15 producers represent around 35% of the production[9] and the top 100 producers represent around 55% of the total EU production. The largest players are *VION* (NL), *Danish Crown* (Denmark), *Tönnies* (Germany) and *Bigard Group* (France): their combined turnover reached 23 billion euros in 2010. The supply chain includes farmers who breed animal, slaughterhouses (transport, slaughter and deboning operations), traders and processors. Many players engage with long term partnership with farmers and integrate the slaughter, deboning and transformation operations.

[8] http://ec.europa.eu/agriculture/statistics/factsheets/pdf/eu_en.pdf
[9] http://ec.europa.eu/dgs/health_consumer/information_sources/docs/ahw/pres_24102012_opening_4_richard_brown_en.pdf



3.2.1 Needs and demands

3.2.1.1 Safety and hygien

Meat sector needs tools to detect chemical residues (e.g. veterinary drugs), microbiological contamination (e.g. salmonella), to control **online microbiological quality** of products (pathogens and/or total flora) and sterilization. Companies are willing to perform additional tests to guarantee safety of the product according to HACCP and voluntary measures. Rapid and simple methods to **measure the formation of compounds** resulting from transformation processing or their migration related to the interaction between the container and the product are also a crucial need.

3.2.1.2 Quality control

The meat industry needs fast and reliable quality information **throughout the whole production process (slaughtering, deboning/cutting, transformation)**, which would ultimately provide a quick and guaranteed classification of the raw material for the production of the adequate products (among others, cooked or cured hams). The main demand of the industry for that subject is to measure the instant **meat tenderness** and track its development to predict time of maturation and optimum of tenderness.

a. Slaughtering

The first need is to measure, verify or **control animal stress** from the cattle farming sites up to the slaughtering places with automatic sensors. It could be also helpful to have a measure of the **stunning efficiency** to verify that the animals are unconscious before "bleeding" operations. Another demand is to be able to **monitor the changes in the product** temperature and pH, during the cooling phase of meat carcasses.

b. Deboning/Cutting

Online measurement and evaluation of the **meat tenderness and meat maturation** is a demand that microsystems could answer **without being invasive**. They could also help measuring the pH of meat, which is a crucial indicator of the process for the conservation.
Microsystems could be a solution to **understand** oxidation process of meat after deboning, **and** to **anticipate oxidation** by creating new indicators.

c. Processing

Measure of drying surfaces evolution (to avoid the creation of a too dried layer at the surface) is an important demand. Microsystems could also **measure mechanical energy** (kneading, friction, etc.) transmitted to the muscles during the churning operation for the production of ham.

During the cooking of ham, fluorescence spectroscopy measurements to **predict the cooking output** (loss of meat juice) and predict the **stability of the emulsion** would be of interest; as well as the **measure of volatiles particles** to control the smell of ham, of roasted products and to monitor the maturation of the meat. Tools do verify **mixing homogeneity** of ingredients and minerals in sauces, or minced meats are missing.

Finally, industrials need smaller sensors to monitor temperature and pH to respectively control cooking or sterilization phases and **the acidification kinetic** at the centre of the meat

3.2.1.3 Other issues

Further topics of interest include:

- Traceability: miniaturized systems to track animals, products and containers along the production lines more cost-effective than the RFID chips already used.
- Content of GMO in soya feed.
- Animal welfare: air control in the stable by gas sensors.
- Implementation of MST in the automation of technical processes.
- Sustainability, organic food, regional food, carbon foot print and food chain management in general…

3.2.2 Constraints for implementing microsystems

Nearly all the needs listed require non-invasive and non-destructive methods of measurements. This could be an advantage for the microsystems and the smart sensors but it still implies **more constraints** for their implementation.

Processed meat products generally present a high heterogeneity: disparity of structure and tenderness inside a muscle, disparity of treatment inside a dryer due to the differences between meat pieces. A major constraint is thus the

representativity and validity of the measure. Indeed, the smaller is the sample, the better it is to avoid waste, and the microsystems are good devices to do that provided they are **accurate** both in terms of positioning and measurement. They also have to be **adapted to the current equipment** of the industry, including the IT and automation systems.

In order to have continuous measurements during a long period of time, devices have to be implemented online. Wireless sensors embedded in food products can also provide interesting measurements. This implies that they have to be **autonomous, to support cleaning and not to add contamination problems**. Special attention should be given to the **hygienic aspects** of these devices: it must be easy to clean (also with strong detergents) and not a contamination source on its own. A lot of solutions have already been found but they are only available at laboratory scale.

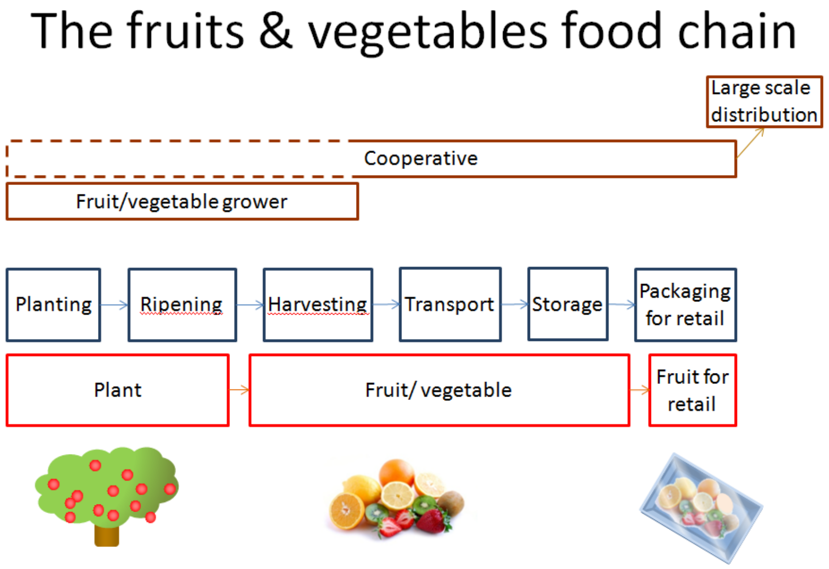
Overall, devices have to be **small, robust and cheap** to be adopted by the meat industry. Another problem is related to the confidentiality of the data collected thanks to new sensing systems, considering the possible reluctance of the food chain operators to share data related to their products.

3.3 The fruits and vegetable sector

In 2011 the EU fruit and vegetable sector accounted for 20% of the value of the EU agricultural production. The combined output of the fruit and vegetables was estimated at 75 billion euro[10], with around 550 000 employees and 1.4 million farms holdings[11]. In 2005, there were 10.000 companies processing fruits and vegetable, 42.500 specialized wholesalers and 76.000 specialized retailers in the EU-27[12].

A large majority of the fruits (90%) and of the vegetables (80%) are consumed as fresh products. Other types of consumption include cans (8% for the vegetables, 4% for the fruits), frozen (6 and 1%) and fresh-cut (4 and 1%)[13]. The production of fruit and vegetable is very regionalized and concentrated in a few countries. For example oranges are mainly produced in Italy and Spain (80% of the EU production) while onions are mostly grown in Spain, the Netherlands and Poland (80%). The sector is less concentrated than the milk or the meat sector. Large companies include *Pomona, Dole, Bonduelle, Agrial, Bakkavör, Salico, Hessing Supervers, Vezet, or Natures Way Foods.*

[10] http://ec.europa.eu/agriculture/statistics/factsheets/pdf/eu_en.pdf
[11] http://www.gis-fruits.org/Documentation/Bibliotheque/European-Fruit-Sector
[12] http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-08-060/EN/KS-SF-08-060-EN.PDF
[13] http://www.freshconveniencecongress.com/resources/documents/1308561709cindyvanrijswick.pdf



3.3.1 Needs and demands

3.3.1.1 Safety and hygien

Assuring consumer security and **satisfying regulatory constraints** are the main demands of the fruits & vegetables sector:

- Microbiological quality: three kinds of organisms, presenting a risk for human health, are likely transported by fruits and vegetables: viruses (hepatitis A), bacteria (Salmonella, E. coli…), in most case, and parasites.
- Phytosanitary quality: maximum residue levels (MRL) are established by considering the consumption habits and fixed for each combination (fruit or vegetable/approved pesticide).

In most cases, products are sold before the results of the analyses are known, so **rapid methods for the detection and quantification of contaminants** with a sanitary risk for the consumers are needed.

3.3.1.2 Quality control

Improving the global quality of the offer is always a need. Microsystems could provide a system that enables the correlation between physicochemical properties (colour, texture, volatile compounds) and organoleptic quality. There are several demands from the industry, related to the **key points of the production** of fruits and vegetables. Transversal needs such as the independence from expert laboratories also emerged.

a. Fast phytosanitary analyses

Fertilization is necessary both for open ground and soil less. During production, preventive treatments with phytosanitary products are generally applied to avoid diseases linked to a plant contamination by viruses or parasites which could lead to production losses up to 30% of the harvest. Therefore, **rapid methods** to **detect and**

quantify residues of phytosanitary products are a demand of the industry. To reduce the variation in treatment, a **quick method to detect contaminants** representing a risk for the crops will be helpful.

b. Ripening and harvesting period

For fruits and vegetables, firmness and colour are the main parameters used **to evaluate the ripening**. To avoid or at least limit harvest losses, microsystems could provide new kinds of measurements.

3.3.1.3 Other issues

a. Storage

Regulate temperature and hygrometry is essential to control breathing and sweating (which can lead to modifications of the aspect or the texture) but also to limit post-harvest losses due to the growth of microorganisms in storage platforms. So a **system for the storage management** (for products with a long storage period such as potatoes or apples) is a need.

3.3.2 Constraints for implementing microsystems

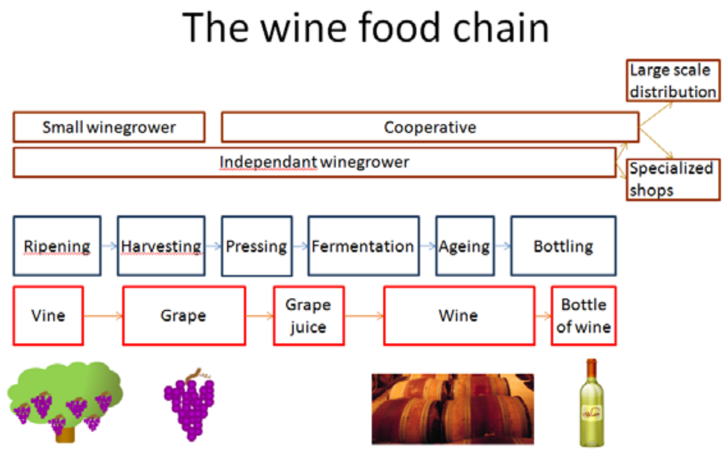
As in other food sector, the **investment margin is low**. This is especially important as the fruit sector has lengthy production cycles resulting in delayed return on investment. Therefore efficiencies to ensure productivity, profitability and safety must be continuously implemented to be competitive. Innovations have to be **easy-to-use** and designed as a decision support tool.

3.4 Wine sector

The EU is a leading producer of wines. With around 15 billion of output in 2011, the wine sector represents 5% of the total agricultural output. The structure of the wine sector is very different than the one of the meat or dairy industry due to the importance of small businesses. Two types of business models coexist: independent wine growers who cultivate their grapes, produce and commercialize their wine and larger companies (often cooperatives) that collect the grapes from vine growers and transform it into wines. In the EU there are around 600.000 wine growers producing quality wines and more than 1.75 million of farmers involved in the production of "other wines". The production is concentrated in a few countries: France, Spain and Italy accounts for 80% of the EU wine production. Other producing countries are Portugal, Greece, Hungary, Romania, Bulgaria and Cyprus[14]. EU production accounts for 65% of global production and 70% of export.

[14] http://ec.europa.eu/agriculture/evaluation/market-and-income-reports/2012/wine-sector/full_text_fr.pdf

The wine market is very dynamic and exports play a major role in the development of the sector: the demand for wine is expected to increase by 10% between 2012 and 2016, due to a spectacular increase of the consumption in Asia (+40% in China)[15].



3.4.1 Needs and demands

3.4.1.1 Safety and hygien

Although quality is the main driver of the wine sector, safety improvement is also a demand of the producers. They need fast analysis methods for different parameters in the laboratory: in-situ at the reception of the raw materials and on-line detection systems that could lead to 'intelligent tanks', 'intelligent corks' and 'intelligent labels'. They also require instruments to measure safety parameters such as: detection of foreign bodies in the bottles, multiresidues in the wine, ochratoxin, fumonisin, aflatoxin, biogenic amines, heavy metals, histamine, lactic bacteria, prevention of volatile phenols.

Cleaning issues could be addressed by microsystems with the **on-line control of cleaning** and therefore allow saving water in the process.

3.4.1.2 Quality and process control

Overall, wine producers require continuous, more frequent and precise measurements to better control the quality from the **grape production to the wine elaboration**. Transversal needs such as the independence from expert laboratories also emerged.

[15] http://www.viti-net.com/actualite/international/article/de-plus-en-plus-de-vin-consomme-au-niveau-mondial-mais-pas-en-france-12-86201.html

a. Grape production

To ensure the quality of the wine, microsystems could help the precision viticulture, and **measure upstream parameters** such as grape classification (quality/state) on entry to the cellar and assessment of the filtration and the clarification. A method to assess the maturity of the berries by a non-destructive method with an acquisition speed sufficient to work at a line speed of 2 m/s would be of interest

b. Process and elaboration

The **oxygen rate and activity control** throughout the winemaking process is today a major objective in wineries. Control Quality (monitoring committees, results of international wine challenges ...) showed that, for the wines detected as faulty, a high issue frequency of problems is related to oxygen management (oxidation, reduction).. The monitoring of other **crucial parameters** (**organoleptic valuations in must,** gluconic acid in grapes, fermentation with alcoholic content, automatic measurement of density, sugar on-line, faster total sugars, ensure fermentation in the bottle), **chemical reactants** (sulphide/mercaptans, free SO_2, NH_4^+) and **quality parameters** (organoleptic objectivity, monitoring indicators of the authenticity of the wine) could be addressed by Microsystems. Smilarly, the **assessment of physical or chemical parameters** (control of the pressure in the bottle, potential redox in the bottles) and the **counting of viable yeast cells** would be of interest for the sector.

3.4.1.3 Other issues

The other issues concern:

a. Traceability

To guarantee traceability depending on knowledge of the environmental conditions, sensors integrated into the label can measure temperature, light and humidity.

b. Packaging

Microsystems could improve the bottling operations and facilitate measurements of interests such as the presence of trichloroanisol (TCA) in corks.

3.4.2 Constraints for implementing microsystems

In the wine sector, while cost is the first concern of the producers, experts rather prioritised reliability. The wine industry is not against innovation, but they require that the microsystems satisfy certain criteria. **Time, cost and reliability** of the measurements are the most important factors that must be considered for the implementation of microsystems. These ones have, of course to be **user friendly, robust** and their maintenance must remain simple.

3.5 Packaging sector

The packaging plays a major role in the innovation of the food industry: it preserves foods, guarantees their safety and it is closely linked to the image of the food products. Marketing plays an important role together with technological and environmental aspects. Research is mostly focusing on new materials (more environmentally friendly, often produced from bio-based resources and easily recyclable), on active packaging (packaging that interacts with the food product e.g. to maintain its quality or extend its shelf-life) and on intelligent packaging (packaging that has the ability to provide information e.g. on the evolution of the content quality, its storage conditions).

The food industry is rarely involved in the production of packaging, they rely usually on specialised suppliers. The market is divided into plastic, glass and metal and paper-based packaging.

3.5.1 Needs and demands

3.5.1.1 Food preservation

Depending on the requirements of packed foods, the application of appropriate active packaging systems can significantly **reduce food quality deterioration**. Food packaging conditions play an important role in the shelf-life of food, include physiological processes (e.g. respiration of fresh fruits and vegetables), chemical reactions (e.g. lipid oxidation), physical processes (e.g. dehydration) and microbiological aspects (e.g. spoilage by microorganisms).

Oxygen scavengers are the best known applications used in active packaging. Besides the oxygen scavengers, antimicrobial agents, moisture absorbers, ethylene absorbers, ethanol and carbon dioxide emitters can be used as active features in order to address the weak points in the shelf-life of packed goods and need to be developed.

3.5.1.2 Quality control

Monitoring the quality of food is also a need expressed by the food manufacturers and developments are requested for **intelligent packaging**, such as time-temperature indicators (TTIs), freshness indicators and tracking services to enable (i) to track with respect of the cold chain, (ii) directly detect product quality of the packed food (e.g. detection of volatile and non-volatile compounds, detection of the presence of microbiological metabolites), (iii) take the right decisions in terms of logistics (delivery, storage) in order to avoid product spoilage.

3.5.1.3 Other issues

a. Packaging materials properties

To meet consumer expectations and environmental challenges, packaging manufacturers are now seeking to develop packaging which is more light-weight according to the prevention of packaging waste and materials from bio-resources (eco-biodegradable packaging). However, the materials developed do not have suitable properties to meet the requirements of the applications. Industrials need **materials to improve gas transfer properties, mechanical properties and stability.**

In addition, the development of materials with **surface properties to reduce microbial adhesions** is also a need to avoid microbial contamination from packaging to food product.

b. Shelf-life of packaging materials and traceability

Depending on their nature and conditions of storage, packaging materials are able to age faster or slower. To assess their ageing and their shelf-life, it would be useful to resort to the **inclusion of tracers** in the packaging materials. Similarly, the insertion of matrix tracer would facilitate the recovery and recycling of packaging waste after consumption. Another aim of the indicators is be to avoid counterfeits.

c. Packaging & Cold chain management

Microsystems could provide non invasive methods to co**ntrol the leaks of conditioning gas**. They can also be a solution for the **monitoring of the cold chain** in terms of time and temperature such as RFID combined with WSN / Intelligent container for storage and transport.

3.5.2 Constraints for implementing microsystems

The introduction of new packaging is subject to compliance with regulatory requirements. Regulation EC 1935/2004 on materials and articles intended to come into contact with foodstuffs specifies: "*Food contact materials shall not transfer constituents to food which could endanger human health, bring about an unacceptable change in the composition and bring about deterioration in organoleptic characteristics*" and regulation EC 450/2009 on active and intelligent materials intended to come into contact with foodstuffs states : "*Substances should undergo a safety assessment by EFSA before they are authorized for use" and "Intelligent systems that are on the non-food contact surface of the package have to be separated from the foodstuff by a functional barrier, i.e. a barrier to any migration*".

Another aspect to take into account concerns the **acceptance** of micro-systems by the consumer and the **environmental impact** of the use of micro-systems on the recyclability of packaging.

Finally, as in all the sectors, the **additional cost** associated with the use of innovative products with respect to margins generated in the food industry has to be taken into consideration.

4 Synthesis

4.1 A significant market for microsystems

The food sector represents a significant market for developers of microsystems solutions. In the EU, there are more than 270.000 food processing companies and 3.7 million of farms above 5 hectares (12 million of farms in total). These numbers do not take into account the suppliers of the food industry (packaging, equipment, laboratories), the transporters, wholesalers or retailers.

Some production like the dairy or the meat food chains are very concentrated and dominated by multinationals while other food chains like the wine or the fruits & vegetable are more regional with many small producers. There are a limited number of multinational companies with a global position: 14 companies have an annual turnover above 20 billion usd as illustrated below.

Rank	Company	Food Sales ($ millions)	Year Ending
1	Nestlé	99,733	Dec. 10
2	PepsiCo, Inc.	57,838	Dec. 10
3	Kraft Foods	49,207	Dec. 10
4	Anheuser-Busch InBev	36,297	Dec. 10
5	The Coca-Cola Company	35,119	Dec. 10
6	JBS	31,285	Dec. 10
7	Archer Daniels Midland Company	31,000	Jun. 10
8	Unilever	30,160	Dec. 10
9	Mars	30,000	Dec. 08
10	Tyson Foods	28,430	Sep. 10
11	SABMiller	28,311	Mar. 11
12	Cargill	26,000	May 10
13	Danone	22,530	Dec. 10
14	Heineken	21,370	Dec. 10
15	Kirin Brewery Co.	19,545	Dec. 10

Source: Global Food Markets (GFM), Leatherhead Food Research.

If the key drivers that may determine the implementation of microsystems are similar from one food chain to another, there are important differences in terms of structure of the supply chain, type of actors involved and there are important “cultural differences”. These differences may represent a barrier for companies interested to supply the food industry with new microsystems devices: the food industry does not represent a unique market, it is actually constituted of several different markets (dairy, meat, fruits and vegetable, beverage etc.).

4.2 The demand expressed by the food industry

The food sector is facing several simultaneous challenges:

- To guarantee food safety,
- To improve the quality of the food products,
- To decrease its impact on the environment,
- To provide affordable food supply to a growing population.

New technologies can contribute to address these challenges. For this reason, it can be considered that **safety, quality, sustainability and efficiency represent the main drivers** for the implementation of microsystems in the food sector.

The need for microsystems is geared by these drivers: in this study, the industry consulted in the five different areas (dairy, meat, wine, fruits & vegetables and packaging) expressed a strong demand for solutions that help to ensure food safety and food quality. Solutions that can improve the sustainability of the food production and reduce costs are also a demand, in particular for the optimisation of water and energy consumption.

The consultation of the food industry reveals that there is a **strong demand for sensors** in all the sectors examined of the agri-food industry. Microsystems can actually match two of the most important concerns of this industry: guaranty the safety and improve the quality of the food products.

To ensure the food safety of a product from the raw material up to the end product is essential, since a spoiled first material might mean a contaminated product and a product recall with disastrous effects for a company. Early-stage detection is very critical given into account that it can prevent food scandals or pandemics. It is important to obtain fast and accurate microbiological analysis, to be able to give margin to time dependant Critical Control Points by detecting pathogens. Other types of pathogens (pesticide residues< toxins) or unwanted substances (like hormones or GM-food given to animals that organic products should not contain) could be traced with microsystems.
Detection of compounds is another need: contents of neo-formed compounds could be followed during the cooking to better understand their formation
Micro-organisms metabolites could be track to measure spoilage and contamination. Intelligent packaging which could monitor the deterioration of the product and increase the shelf life could also include microsystems. Hygiene could also be improved by non-fouling surfaces thanks to surface treatments.
Finally, concerning the seafood sector (cf. annex8), one important point concerns the urgent implementation of rapid methods and innovative microsystems to detect and quantify biotoxins for food safety and health care application.

To improve product quality, microsystems could help optimising the processes or designing new ones, and help controlling them continuously. They could allow fine monitoring of kinetics of pH or microorganisms for fermented products like cured meat or cheese. The detection of compounds specific to the quality of the produced food is also relevant: ethanol and gas detection could allow monitoring fruit and vegetable metabolism, the measurement of volatiles compounds could help control the cooking of meat etc.

For water and energy, sensors allowing to monitor and optimise their consumption are needed. For the dairy and the wine production, solutions for optimising the cleaning operations are particularly in demand.

Microsystems could also help to tackle **horizontal issues** such as intelligent packaging and traceability. The recent "horse meat" crisis reveals a demand for solutions allowing authentication and detection of fraud.

There is a demand for two main types of sensors: portable devices for fast and easy-to-use in situ measurements and sensors integrated in the production lines.

For **portable devices** the concept is similar to the Point-Of-Care Testing (POCT) used in medicine: the idea is to allow in-situ measurement for a rapid measurement. Such device are usually handheld and they must be easy-to-use and sufficiently robust to resist to rough conditions. Examples of applications include handheld devices for animal health and welfare testing (air control in the stable) or devices for testing the quality of the raw materials (evaluation of the ripening of fruits and vegetables in the fields to determine the time of harvesting, quality assessment of the grapes at the reception of wineries).

Sensing systems embedded in the production lines can be on-line, in-line or at-line. The main need is to obtain continuous measurements of simultaneous parameters relevant to food safety and food quality. Rapid, multi-parameters and continuous measurements are asked by all the sectors. Sensors which do not need any sample preparation and which are not invasive or destructive are also a needed.

1) Off-line measurements are realised in a laboratory (environmentally controlled location) by technically trained personal.
2) At-line measurements are realised in the production area and is performed by an operator
3) On-line and in-line measurements are fully automatized systems realised into the process stream. Usually, in-line means that the measure is realised into the main process steam and on-line means that the measure is made in a bypass of the main stream.

The application can concern an evaluation of the raw and in-process materials as well as the monitoring of food processes. In process foods, they can allow real-time monitoring of key parameters which in turn will help to understand the influence the raw materials and of the process parameters on the quality of the final products.

Such systems could actually bring considerable innovation as the possibility to acquire long series of data will give access to knowledge currently not available.

These solutions should be embedded in the process management systems of the industry to allow actions that optimise the production. They can be integrated in Decision Support Systems or part of a Process Analytical Technology (PAT) system by providing continuous measurements of the Critical Process Parameters (CPP) which affect Critical Quality Attributes (CQA). Ideally, the principles of "Process Analytical Technology" as applied in the pharmaceutical industry could be transferred to a food production chain, making the whole process safe, guaranteed, clean and effective. In practice, the food industry has not the type of profits required for such an effort. The measurement solutions should therefore be dimensioned to the needs of the companies.

Microsystems could also lead to intelligent systems: sensors coupled to controllers could optimise to change the atmosphere of the room for fruit storage, sensors which could correlate the sensorial parameters to physicochemical analysis. For wine, intelligent tank could follow and regulate fermentation, intelligent corks which could regulate the exchange with the environment etc.

4.3 The constraints for implementing microsystems in the food industry

The microsystems need to be cheap, to have a good return on investment and to have a low operating budget with easy maintenance. Then they must be robust and resistant to cleaning without decreasing the cleaning efficiency of the plant. The sensors have to be reliable and precise. Another constraint mentioned is the ease of use of the technology.

Economical constraint

The first constraint highlighted by the industry is the cost and the return on investment. It means that new detection and measurement solutions are not a need per se: the results of the measurements should trigger actions that should be cost-effective. They can for example help to optimise the use of inputs or the parameters of a process and help to reduce costs by reducing the quantity of raw materials or the consumption of water or energy. An improved monitoring of the production (safety and quality) can also avoid waste by reducing the amount of non-conformity of the products and lead to an increase in profit since consumers will tend to buy the most reliable brand (given the food scandals of the past few years). These aspects have to be taken into account at an early stage of the design of the innovative solutions based on microsystems. Microsystems can turn to an antagonistic advantage over other companies that do not have on-the-spot controls or continuous monitoring of their products. An accurate cost-benefit analysis is required to present food companies with the adavantages of such systems.

Technical constraint

The evolution of Microsystems for food applications will depend on the ability to provide solutions to the following technical points:

- The reliability and sensitivity must be better than actual methods or at least equivalent;
- The compatibility with a food process: it must be grade food;
- The integration into the process (non-invasiveness preferably) and the communication with automatisms must be facilitated;
- The surface must be easy to clean and resists to severe cleaning procedures cleaning process to avoid any risk of contamination;
- The test result must be available in the shortest time, in order to save expending efforts and work on a product which is not compliant with standards.

Practical constraint

The innovation developed mustn't bring complexity. The system must remain easy to use to be adopted by the industry.

Commercial/market constraint

For a successful uptake of innovations by the food industry, it is necessary to demonstrate the added value of the new product. In the case of measurement solutions, it is of primary importance to anticipate how the industry can benefit from the results of the measure. This has to be taken into account at a very early stage of the development of the new solutions and for this, a very good knowledge of the practices of the food producers is needed. Partnerships with companies supplying equipment to the food industry can represent a good strategy to overcome these constraints.

5 Conclusion

This report provides a synthesis of the views expressed by the industry regarding the needs and constraints for implementing microsystems in the food sector. More than 100 food companies from Estonia, France, Germany, Spain and the Netherlands have been consulted in workshops and interviews during the preparation of this study.

It reveals that there is a strong demand for solutions that help to address the four main challenges of the sector: safety, quality, sustainability and efficiency. Microsystems can bring considerable progress for the control of food products, the monitoring of food processes and they can help the industry to optimise its operations. Besides the price and the necessity to provide reliable and robust solutions, the main constraint for implementing microsystems in the food sector is of an organisational nature. It is very unlikely that a single solution will fit the requirements of all food chains. Supplying the food industry with new equipment also requires a very good knowledge of the food sector targeted.

The prices of microsystems can drop if they are produce in large quantities. However, lowering technology costs by volume production would first need some development loops which have to be financed, and then there is still the Hen-Egg problem remaining that first the mass production has to start before prices go down. To overcome the difficulty to enter the market, partnership with equipment providers of the food industry can be an effective strategy.

The most interesting way for industry to make use of microsystems will be by showing real examples during international exhibitions (e.g. IFFA, SIAL…). If it would be possible to produce prototypes, which represents microsystems, they could be the door opener to industry.

This report will be used in *FoodMicroSystems* for the construction of three technological roadmaps. This report is complemented by 3 other report focusing on consumers' perception, ethical issues and regulatory situation. These reports will provide a more detailed framework to guide researchers and entrepreneurs of microsystems solutions in the development of applications for the food sector. For more information, please visit www.foodmicrosystems.eu.

6 Annexes

6.1 Annex 1: Preparation table for the meat industry

2 internal ADIV meetings were organized in the beginning of the year to identify in the different meat sectors the main problematics. The results can be synthesized in this table. It divides the meat sector in different sub-activity (longitudinal sub-activities: Slaughtering, Deboning/cutting, Transformation, Conditioning; and transversal activity or items: Tractability, Tenderness, Analyses, Neoformed particles). For each of these sub-activities, different thematic or problematics were identified.

Table.2. Synthesis table of technological needs for Microsystems development in the different activity of the meat sector:

Meat sector activities	**Slaughtering**	**Deboning/Cutting**	**Transformation**	**Conditioning**
	Analyses			
Thematics or Technologies Thematics or Technologies	*Measure of animal stress*	*Measure/evaluation of the state of meat maturation*	*Measure of drying surfaces evolution (creation of a dried layer at the surface of meat products)*	***Intelligent packaging*** *Leak indicator (gas tightness of the packaging)* *Cold logistics: Time/Temperature indicator*
	Measure of stunning efficiency	*Ph Measuring*	*Measure/evaluation of mechanical solicitations applied to meat muscles during churning and malaxing operation (production of ham)*	
	Measure and control the kinetic evolution of Temperature/Ph during cooling phase	*Oxydability indicator of muscles after deboning*	*Predictive evaluation of ham cooking output (lost of meat jus)*	
	Tractability *Miniaturized systems for animals/products/containers tracking along the production lines (Ex: RFID chips)*		*Emulsions quality evaluation*	
			Time/Temperature indicator to control cooking or sterilization phases	
	Tenderness *Meat tenderness evaluation on carcasses, quarters or muscles products*		*Verification of mixing homogeneity (sauces, minced meat, etc.)*	
			Control of acidification kinetic	
			Volatiles particles measurement (smelling)	
	Analyzing *Online indicative measurement of microbiological quality of products (Pathogens and/or Total Flore)*			
			Neoformed particles	
			Detection/measure of neoformed particles resulting from transformation processing (cooking process, smoking process, etc.)	*Interaction between container/product with neoformed particles releasing onto/into the product*

6.2 Annex 2: Netherlands dairy workshop report

HTE / FMS workshop on Innovative Processes and Methods for the Dairy Industry

June 7, 2012, Wageningen, the Netherlands

1. **Opening**

Charon Zondervan (FBR, WP leader of HTE) opens the workshop by welcoming all (21) participants. Short tour de table. He presents the structure and objectives of the workshop and the two projects HTE and FMS.

2. **Session 1 – Separation, structuring and pervaporation**

Presentation by Cees van Rijn (Aquamarijn)
SiN membranes with very well defined pores (100 nm and up) are used to sieve components from milk or beer or in a reversed process to make emulsions of e.g. oil droplets in water or foams of e.g. aerated desserts. Because of the very high uniformity of the pores, the thinness of the membranes and the unlimited control over the shape of the holes, the characteristics of the end product can be controlled to a very high extend. Remarkable are the relatively high throughputs (40 -100 x higher flux, when compared to conventional filtration). Filtration units on industrial scale are already commercial available for the beer industry.
Presentation by Frans Velterop (Pervatech)
Very small pores (less than 1 nm) are created in a ceramic membrane. Ceramic membranes with pores < 1 nm are typically used for dehydration and removal of small molecules from larger mw Dalton solvents. Contrary to dehydration, Pervatech offers also organophilic membranes to remove organics from watery streams. These membranes can be used to extract specific molecules from the product stream (e.g. aroma's, off-flavours, etc.). The intermediate products in the manufacture of the ceramic membranes for dehydration can be used also for emulsification, were we can set the desired pore size from 1 nm up to 100 nm. Indicative experiments show potential of the ceramic membranes for the reversed process to produce emulsions.

3. **Session 2 – Sensing and detection**

Presentation by Aart van Amerongen (FBR)
Biomolecular sensing and diagnostics. Carbon nanoparticles are very cheap. They enable detection limits of low picomolar levels.
Microarrays in combination with PCR. NALFIA (pregnancy test). The time determining step is the PCR, which takes 30 min. This means that the results are available in about half an hour.
The method works in different matrices (faeces, blood, milk, etc.) but the sample does need some pre-treatment (e.g. filtration).
Very promising is the combination of NALFIA with microarray technology. It overcomes the draw-backs of the separate methods.
The Ostendum technology is an optical method which in potential is very sensitive. It is label-free.

4. **Session 3 – Lab on a Chip**

Presentation by Karin Schroën (Wageningen University)
Use of microfluidics for emulsification, to determine the stability of emulsions and aspects beyond emulsions. Scientific presentation on the study of how emulsions are formed and how droplets coalesce into larger droplets, a process that determines the stability of the emulsion.
There are several advantages with the use of microfluidics in these kinds of studies (monodisperse, control of the process, etc.).
Microsystems can be used to produce encapsulation systems with very specific release characteristics.

6.3 Annex 3: Interviews of French dairy companies

Details on the cheese making process

Cleaning

Currently, checks are performed to monitor the effectiveness of cleaning:
- upstream controls to check the good application of instructions for use of detergents to bring a good efficiency to cleaning products (detergent concentration, exposure time and temperature);
- monitoring of water consumption and products used by the cleaning station is also carried out (weekly or monthly) to identify any drift;
- testing with colored pH indicators are also used to visually evaluate the quality of rinsing;
- regular visual inspections of surfaces (wall tanks, valves inside…), detergent solutions and rinsing solutions can allow to identify dysfunction in the cleaning step;
- disinfection monitoring is performed by direct or indirect bacteria count:
  - quantitative tests which measure the whole population of microorganisms present on the surface. Depending on the desired response time, these tests are performed either by conventional counting or by indirect method like ATP-metry.
  - qualitative tests for determining species of microorganisms. In some cases, whole microbial count is not good enough to evaluate the effectiveness of cleaning. The absence of pathogenic species is often necessary to demonstrate the effectiveness of the cleaning plan.

All these tests give an idea of the fouling and of the level of bio-contamination at a given time but they are not sufficient to control the process of cleaning and disinfection. This evaluation is only possible through the use of online sensors related to the automation which drives the cleaning station.

Microbiological analysis

Under some signs of quality, the specification indicates that the maximum time between the oldest collected milking and renneting is 24 hours (protected designation of origin Mont d'Or, Morbier, Comté). This short time does not allow having the results of microbiological detection of pathogenic bacteria (Listeria, Salmonella) before the processing of milk. For example, conventional analysis in Salmonella and Listeria requires a period of 48 hours before obtaining results.

In addition this obligation about the time between the oldest milking and the milk processing is often associated with the obligation to process raw milk. Thus pathogenic bacteria are not destroyed during treatment of milk (heating treatment, filtration) and the initial contamination of milk (often low) will develop in the cheese and reach dangerous levels for human health. Furthermore, the presence of pathogenic bacteria in the dairy plant increases the risk of colonization of the plant environment with these bacteria with the ability to form biofilms which are subsequently very difficult to eradicate.

Process

Analyses identified during the interviews are detailed below.

Milk clotting:

Milk clotting by acids or enzymes is closely related to the structural organization of the casein micelles. Lactic clotting is caused mainly by lactic acid bacteria that convert lactose into lactic acid. Acid production will lead to the decrease in pH of milk and will trigger the coagulation of milk. Enzymatic clotting is caused by the use of proteases. The mechanism of action of proteases is to hydrolyze, among others, K-casein.

In cheese making, the control parameters of clotting are the setting time (time between the addition of the enzyme from the beginning of visible flocculation), the hardening time between the flocculation of milk and the beginning of cutting the coagulum, and the speed or rate of firming. The total time for coagulation is the time between the addition of the coagulating enzyme and the beginning of the cutting step.

To achieve a maximum yield of cheese and the best quality of cheese, the cheesemaker is looking for a precise determination in continuous of the firmness of the coagulum for optimal cutting.

The importance of knowing the parameters related to coagulation is the fact that the decision of time for cutting the coagulum is a crucial step in the cheesemaking. But the appreciation of this cutting time is relatively empirical and it is currently achieved with simple means such touching or viewing.

If the curd is cut while it is still very tender, the yield is reduced due to a greater loss of protein substances, fat and curd (very small curd grains not retained in the mould). In contrast, if the curd is cut while it is too firm, draining of curd will be slowed and cheeses will be too wet.

Moreover, changes in equipment (closed tanks) and labor legislation (safety), the increase of the size of cheese plant and the increasing importance of automation explain the need of an objective instrumental method online and in real-time for the monitoring of clotting characteristics.

Dry matter:

The draining of whey outside the curd during the step in vat or in mould is very important for the final quality of cheeses. The humidity will determine the evolution of cheese during ripening (kinetics of enzymatic reactions and growth of different bacterial species). Presently, the analysis of dry matter on cheese requires the achievement of a destructive sample. Moreover, there is no method to measure the draining of whey in vat. However this parameter is critical to determine the time of moulding the curd. Presently, the time of moulding is determined by an empirical test ("test du pâton" in French). As for clotting characteristics, changes in equipment and the increasing importance of automation make it even more relevant the need for a measure of dry matter online and in real time.

Whey protein and denaturation rate:

To increase yields, dairy industries apply to milk important heat treatments to denature the whey proteins which become insoluble by associating with the casein. They can thus be recovered in the curd and be better valued. Rates of denaturation are determined by graphs obtained at a moment by experiments. The monitoring of rate of denaturation would improve regularity of yields and decrease the standard deviations of weight. This will allow a lower average weight of the cheese with an increase in profitability.

Opening characteristics:

In the case of cheese of high size with openings (like Emmental), the detection of openings is detected by percussion and trier sample. This method requires real expertise. Moreover, at the time of cutting wheels, it is common to observe large differences between the "measure" with percussion and reality observed at the cutting step. Furthermore, the "measure" by percussion is particularly difficult as the number of opening is low.

An objective method to determine the openings characteristics of cheeses would allow better management of ripening cycles (out of hot room, temperature, humidity...).

Surface status and monitoring of materials ageing:

On this topic, three themes were identified:

- Qualification and quantification of interactions between materials and cleaning products;
- sensitivity of surfaces to the development of biofilms;
- monitoring of the mechanical properties of a material (for example the porosity of mould and the capacity to evacuate the whey).

6.4 Annex 4: The German workshop on meat

Discussion Workshop with the German Meat Industry Representatives from the "Verband der Fleischwirtschaft e. V." (German Meat Association)
28 August 2012, Bonn, Germany

Notes from the meeting:

Global review on FoodMicroSystems project:

The background and examples of Micro and Smart Systems were introduced by M. Bücking and P. Salomon; furthermore the FoodMicroSystems project was introduced and its objectives discussed.

Specifically the constraints of the meat industry towards attending multiple workshops were mentioned. Also the implications of the EC SME definition of meat producing (or in general food producing) companies, in comparison to more industrial or ICT companies, were highlighted: as meat companies with only a few employees already need a high turnover (due to the small margin), they often don't qualify as SMEs according to the EC definition anymore despite their small staff size. And in such small but not "EC SME" companies, there are often only one or two people, the director/owner and/or the head of quality, who might look for new technologies or methodologies; the rest of the staff is 100% involved in day-to-day work in production, logistics and quality management.

Advice for the roadmapping workshops:

Finally the question was asked, if VDF could help us organise the two (or one of the two) „microsystems – meat roadmapping workshops" or if it could even be jointly organised by the FoodMicroSystems project and VDF.

A few ideas on the objectives and on whom to engage in a workshop were discussed: involve the association in Germany that covers final meat products "BVDF - Bundesverband der Deutschen Fleischwarenindustrie e.V."

as it will be difficult to get many meat company representatives into workshops, "users of microsystems" shall also comprise stakeholder of meat commerce, certification providers, manufacturers of measuring/processing equipment for the meat industry, and food user organisations.

In fact, VDF was interested in organising a seminar on "research for the meat industry" anyway, but could also imagine a joint seminar/workshop with FoodMicroSystems.

Such a workshop could take place in November or later. As a venue, Fraunhofer-IML in Dortmund was proposed (Fraunhofer Institute for Material Flow and Logistics advises companies of all industries and sizes in all questions about material flow and logistics)

Currently we are in discussion to define the content of this workshop.

Some constraints of the seminar/workshop between the interests of VDF and the needs of the FoodMicroSystems project were identified:

it will be difficult to engage representatives from the meat industry in a discussion in English

the planned "roadmapping format" with small table discussions may not be so appealing to members of the meat industry. Reason: Strong completion within the meat industry, therefor it seems impossible to receive detailed information of current challenges and / or problems. At the moment we cannot give a statement, whether this is only a German phenomenon or if this valid for the European meat industry as well.

… these issues have to be discussed…

6.5 Annex 5: Table of results for the French industry of meat

ADIV set up interviews of industrials to have a first feedback of their problematics, but also to get their own point of view and specific problematics and their expectations of Microsystems.

To get more interaction of industrials, ADIV organized a workshop focused on Microsystems, which was included in a global Innovative Technology demonstration day (with robotic demonstration). This workshop was organized at ADIV on the 19th of June. It started by a presentation of Microsystems leaded by Elisabeth DELEVOYE from CEA-LETI. Then an exchange was initiated by Matthieu ALRIC from ADIV to present some examples of problematic preselected to try to have reaction or observation from the audience of industrials, in the objective to have discussions and exchange around Microsystems application in the meat sector.

These interviews and Workshop did not really permit to bring out new ideas and thematic, but it still managed to confirmed some of our ideas and topics for Microsystems developments.

Description tables of the technological needs of Microsystems in the different activity of the meat sector:

Activity	Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Slaughtering	***Measure of animal stress***	Measure, verify or control animal stress all along the manipulations and transport from the cattle farming sites up to the slaughtering places (transport, unloading, waiting time in boxes before slaughtering, etc.)	No automatic control on industrial sites Only experimental systems are developed at the state of laboratory experiments. At industrial level, only physical observations based on compartmental indicators can be or are achieved	Possible technologies: - Encephalogram measurement : interpretation of brain animal waves before slaughtering Example of ongoing development at ADIV : a radio-wave transmission system to measure animal encephalogram Other measurements at research state: - Measurement of blood composition : ▪ Hormones concentration : • Adrenaline/Noradrenalin : indicator of an intense animal stress during a short time • Cortisol : indicator of a long term stress (example : truck transportation) ▪ Plasma composition Example : British system of blood samples extraction and analyzing directly fixed on animals	Industrial constraints make difficult the development of industrial applications and use. Existing solutions stay at research level However, a European regulation, N°1099-2009, will be apply in 2013 : obligation for each slaughtering sites to statistically measure animal « well being »

Activity	Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Slaughtering	***Measure of stunning efficiency***	Verify that animals are unconscious before "bleeding" operations	Measure or observation of animal behavior indicators (lose of posture, lack of cornea reflex, etc.)	Electric signals (encephalograms) or Hormones rates (Adrenaline Noradrenalin, Cortisol) or Blood parameters (blood plasma composition)	Low level of electric signal (between 10 to 100µV) Difficult positioning of the electrodes Large number of measurements to achieve, relative the number of animals which pass through slaughtering sites Needs of wave information transfert (ex: wireless) between sensors and registration system
	Measure and control the kinetic evolution of Temperature/Ph during cooling phase	Measure on meat carcasses of the kinetic evolution of the product temperature and pH, during the cooling phase	Punctual (experimental) measure by Pt100 or thermocouple probes implemented at different points of the carcasses	Classical temperature measurement or Use of thermographic infrared cameras ?	To develop miniaturized "Data Logger" could avoid to have cables between the probe and the registration system To have non-invasive measurement (ex : infrared)

Activity	Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Deboning/Cutting	***Measure/ evaluation of the state of meat maturation***	Online measurement and evaluation of the meat tenderness and meat maturation to improve products valuation	Off line (in laboratory) mechanical characterization (texturometry) of samples or sensorial tests to report on the state of maturation of the meat Problem: Invasive process	Fast (online) measurement/evaluation of rheological or chemical characteristics (hardness, tenderness, elasticity, texturometry, etc.) Measure of the production of particular biological components resulting from the degradation of proteins ("amino acides" = "good evolution" ; "amines" = "bad evolution") Measurement of the production of components resulting from the « lipolyse" (esters, heptane, etc.) which contribute to the evolution of meat taste	To be non invasive To be non destructive
	Ph Measuring	Meat pH (24h after slaughtering) is usually between 5.7 and 5.9. Different factors such as animal stress before slaughtering process can affect the pH, which result in an important decrease of pH (low pH) or a "bad" conservation/stability of pH with high pH. Remarque: pH is one of the most common measure in the meat sector	pH meter specific devices use to achieve systematically control of certain categories of carcasses (labeled meat, example: "Label Rouge") Example of pH meter technology: Xerolite gel probe, equipped with a blade	Parameter measured : pH	To be non invasive to avoid diffusion of microbiological germs and contamination at the measuring point
	Oxydability indicator of muscles after deboning	To know better what are the mechanisms which initiate and conduct oxydability of meat after deboning, to anticipate oxydatability Definition of new indicators	Actually, just measurement of resulting oxidation is possible: - Colorimeter using a chromameter (macroscopic : global image of the product) - Biochemical measures - Spectroscopy	Measure of the RedOx potential Coloration measurement	To have online measurements (actually only achieved in laboratory) To find new biochemical indicators of oxydation

Activity		Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Slaughtering / Deboning / Cutting	Tractability	***Miniaturized systems for animals/products/ containers tracking along the production lines (Ex: RFID chips)***	Animal tracking from cattle farming, to slaughtering, up to deboning/cutting process and conditioning	At cattle farming : plastic label fixed at animals ears At slaughtering or deboning/cutting industries: paper forms or numerical forms centralized on internal network	Parameters so load on the animal form : cattle farming site, date of animal birth, breed, slaughtering site, date of slaughtering, date of quartering, etc.	To have low cost solutions To be autonomous (wave/wireless information transfer) and auto-adaptable to actual computers infrastructure of the industrial sites
			To manage container, trolley, etc.	RFID are used on some industrial sites		
	Tenderness	***Meat tenderness evaluation on carcasses, quarters or muscles products***	Measure of instant meat tenderness and tracking of meat tenderness and its evolution to predict time of maturation and optimum of tenderness	Human appreciation (thumb pressure) Laboratory measurement on samples (texturometry) Sensorial analyses	Rheological parameters and complex characteristics to measure due to anisotropy of the meat structure (different characteristics in the 3 dimensional directions)	To be non invasive Disparity of the tenderness inside of a muscle

Activity	Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Transformation	***Measure of drying surfaces evolution (creation of a dried layer at the surface of meat products)***	Too hard air drying (for cured meats) => a hard rind is created on the surface, what keeps the product from drying correctly	Measurement of Aw of the surface (Activity of water – capacity to release water)	Confidential	Representativeness of the whole dryer which contains different format of products and/or different level of drying
	Measure/evaluation of mechanical solicitations applied to meat muscles during churning and malaxing operation (production of ham)	Measure mechanical energy (kneading, friction, etc) transmitted to the muscles during the churning	None	Calculation of the deformations undergone by ham thanks to d'accelerometers or pressure sensors	Embedded wireless system. Introduction on the surface of the meat pieces or between them?
	Predictive evaluation of ham cooking output (lost of meat jus)	Fluorescence spectroscopy measurement	Availability of a measuring system on site with a penetration probe	Proper functioning of the system for a ham without bones with a surface probe Validation of the measurement with the penetration probe on whole hams before boning on going	Processing of the spectral signal
	Emulsions quality evaluation	Predict the stability of the emulsion during cooking	None. Past development of a conductivity sensor by Cemagref without industrial application	Measurement of the interfacial tension? Measurement by optical method (infrared, fluorescence)?	??????
	Time/Temperature indicator to control cooking or sterilization phases	Make miniaturized and integrated systems	Temperature measurement at the centre of the product with a probe and calculation of the pasteurisation or sterilisation value on a computer (with a wired system)	Already existing devices which need to be miniaturized	Autonomy of the device: 24h of recording every minute Precise positioning at the centre of the product for the conductive products

Activity	Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Transformation	***Verification of mixing homogeneity (sauces, minced meat, etc.)***	Check the distribution of ingredients in a mix of mineral chopped	Salinometer (conductivity of the product in charged molecules): Measuring the salt content (ex: mix with 60 g starter in 1000 kg minced meat)	Measuring the conductivity of the meat mix in several points of the mixer	None
	Control of acidification kinetic	Ph measurement at the centre or Measurement of the assay of lactic acid	Measurement at the center of cured meat with a pH meter electrode	Continuous pH measurement and control of the steaming / drying according to it Continuous measuring system already existing without being coupled to the drying control	Accuracy of the pH measurement in a product whose temperature is changing fast
	Volatiles particles measurement (smelling)	On ham (parallel to the perfumery, roasting, chocolate industries) On roasted / grilled products (eg roast chicken) On maturation of meat with air in a fridge (carcasses, quarters, muscles)	only laboratory devices available: electronic noses	???	Problem: production of many different molecules without knowing those that are the most representative of a good aromatic evolution of the product

Activity		Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Slaughtering / Deboning / Cutting / Transformation	Analyses	***Online indicative measurement of microbiological quality of products (Pathogens and/or Total Flore)***	Detection : 1. Pathogens : Escherichia Coli Salmonella and Listeria Campylobacter 2. Total viable count	Laboratory analysis with bacterial culture from a meat sample Detection method - colony counting with a human eye - molecular biology method (based on bacterial DNA, specific proteins and metabolites) - metabolic activity (respiration of bacteria - CO2 production)	Culture medium: - Components needed for a rapid increase in number, - Elements that will favor a bacterial genus or family Possibility of placing micro-organisms in optimal or very unfavorable conditions. Composition - basis (agar-agar, water,mineral) - pH or oxidation-reduction reaction color indicator (to make assumptions about the genus)	The time required is too long (24 to 48 hours depending on the bacteria analyzed) before results → penalise the manufacturers by keeping them from releasing batches of meat or food Requires a lot of disposable consumables Culture media not always sufficiently selective

Activity	Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Conditioning / Intelligent packaging	***Leak indicator (gas tightness of the packaging)***	Detecting at the level of packaging leaks of conditioning gas	Gas measurement with a probe (%CO_2-%O_2) Measurement of pressure variation	Device: gas analyzer 	destructive method (puncture packaging)
			Leaks indicators	Enzymatic or chemical reaction resulting from the variation in the rate of O_2 (Ageless®)	Adaptation to products packaged with high levels of O_2 (red meats)
	Cold logistics: Time/Temperature indicator	Monitoring of the cold chain	Indicators time / temperature	Puce fraicheur®, 3M monitorMark TTI®	Mass distribution is not necessarily favorable to these devices because their internal cold logistics is not always optimal (non-refrigerated receiving platforms)
			Integrators time / temperature	Warm mark®, Coldmark®, timestrip®	
			Bacterial growth indicators	Traceo®, Checkpoint®, sensorQ®	
			embedded Tracers of temperature	RFID chips	

Activity		Thematic or technology	Objectives	Actual achievement or solution	Parameters / Characteristics	Constraints
Transformation / Conditionning	Neoformed particles detection	***Transformation*** ***Detection/measure of neoformed particles resulting from transformation processing (cooking process, smoking process, etc.)***	Dispose of a rapid and simple methods to measure evolution of neoformed compounds	Spectral analysis techniques: infrared, Raman, UV fluorescence ... (development not realized yet) Systems for monitoring the formation of the crust of grilled products already existing		Absence of development for spectral techniques Is it interesting for cooked products manufacturers
		Conditioning ***Interaction between container/product with neoformed particles releasing onto/into the product***	???	???	???	???

6.6 Annex 6: French interviews for the fruits & vegetables sector

Food Microsystems: needs and constraints in the Fruits & Vegetables sector

1. Preamble

The inventory of needs in Microsystems and the constraints linked to their installation in the Fruits & Vegetables field took place during a discussion with producers in this field. Two meeting took place on July, 10th and on October 2nd 2012 with a representative of the interprofessional association for Fruits & Vegetables (IFLA), manager of the vegetable sector and producers.

1. **<u>Meetings proceedings</u>**

1. Introduction of the Food Microsystems project
2. Short introduction of Microsystems using documents sent by Olivier Chartier
3. Details of the aims of the meeting
4. Analysis of the chain : from crops to distribution, identification of the key steps using HACCP
5. Inventory of the wherewithal currently applied
6. Identification of needs and constraints in the Fruits & Vegetables sector in term of Microsystems

Interviews will be held to confirm generic needs but also to identify specific needs according to the kind of vegetables (roots, leafs, flowers…) and fruits (climacteric or not).

2. Vegetables sector : Analysis of the chain : from crops to distribution

The fruits and vegetables sector is characterized by a high number of species produced, methods of production, ways of distribution and several target markets. The main key steps and their current ways of harnessing are summed up below:

Key point 1: Production

Vegetable can be produced in open ground or soilless. In both cases, fertilization is necessary. Producers take advantage from a technical and scientific support from professional organizations and experimental research for the selection of varieties to be grown and their conditions of cultivation.

During production, diseases linked to a plant contamination by viruses or parasites can break out, leading to production losses up to 30% of the harvest. Preventive treatments by phytosanitary products are generally applied to avoid the diseases outbreak.

Key point 2: Ripening and harvesting period

For fruits and vegetables, firmness and color are the main parameters used to evaluate the ripening. The harvest period can be determined or confirmed by using rapid methods such as degrees Brix, iodine (to determine whether fruit is ripening or rotting by showing whether the starch in the fruit has turned into sugar) or the firmness using a penetrometer.

As far as vegetables are concerned, the harvest date is often governed by commercial constraints. Ripening of vegetables is often evaluated using a visual evaluation.

Key point 3 : Storage

After harvest, fruits and vegetables still develop. They breathe in and gaseous exchanges occur with their environment. The intensity of exchanges depends on the specie but also on the temperature. They can also lose weight due to sweating. These losses vary according to the product but also to the hygrometry conditions. Thus, regulate these parameters (temperature and hygrometry) is essential to control these phenomena (breathing and sweating), which can lead to modifications of the aspect or the texture, but also to limit post-harvest losses due to microorganisms growth.

Temperature and hygrometry control lies with storage platforms. Indeed, fruits and vegetables storage is often subcontracted to platforms equipped with cold rooms fitted with regulation systems.

Packaging and distribution: Fruits and vegetables can follow long or short distributions loops, being transported from producers to wholesalers or retailers. Thus, depending on the case, products are often sold jumbled (pallets) or seldom packaged in baskets with cling-film or perforated film (to be sold in short-loop or directly by the producer).

Key point 4: food safety

Microbiological quality: Three kinds of organisms presenting a risk for human health are likely transported by fruits and vegetables: viruses (hepatitis A), bacteria (*Salmonella, E. coli…*) and parasites. In most cases, bacteria are responsible of diseases associated to the consumption of fruits and vegetables. The main contamination sources reach the product through irrigation, manure or waste from water treatment spreading.

Currently, food safety control of fruits and vegetables is limited to microbiological analyses using classical methods. Analyses are subcontracted to external laboratories. Investigations of viruses or parasites are not very common.

Phytosanitary quality: Nowadays, pesticides are widely used in agronomy in order to improve quality of products and to increase the yield of farming. Pesticides residues in agricultural harvests are regulated. Maximum residue levels (MRL) are established by considering the consumption habits. In France, as in other European countries, a MRL is fixed for each pair (fruit or vegetable/approved pesticide).

The control of phytosanitary residues and heavy metals is performed either by recognized laboratories or by producers by subcontracting. In both cases, classical methods, known as time-consuming and expensive, are used. In most cases, products are sold before the analyses results are known.

6.7 Annex 7: Data of the Spanish wine workshop

Report on the wine Workshop
12th June 2012, Sant Sadurní d'Anoia - Subirats (Barcelona -Spain)

1. Objective

Identify the sector's necessities and the factors constraining the use of microsystems in the wine industry.

Facilitate cooperation among of the value chain actors from research to industrialisation of smart systems in the wine sector.

2. Methodology

To organise the workshop, the format of a round table was adopted for introducing and discussing the concept of micro-systems to the audience. To promote the event and the project, and identify the maximum number of actors both at the level of wine producing companies, and equipment suppliers an agreement was reached

with the INCAVI (Catalan Institute of vines and wines) to organise jointly the meeting about innovation in oenology (see annex). The INCAVI is a Public research Centre at the service of the national wine production and oenological sector.
An introductory power point about the Foodmicrosystems project was used in the presentation and specifically applied to the case of drinks (see annex).
A survey was designed prior to the meeting (see annex) and sent to those enrolled via email, to be returned completed on the day of the meeting. The option of sending it later via email was also given. A round of contributions from the participants in the round table took place.
The surveys and workshop were in the local language.
The workshop was held on the 12th of June in the Guild of the Cava in Sant Sadurní-Subitats (Torre Ramona) which is the capital of the wine-making region of El Penedès and the gateway to the land of cava.

2.1. Prior interviews

To engage the large wine industry in the project and identify the main items, various in-depth interviews were carried out, which helped to define the details of the survey and the focus of the workshop.

2.2. Survey

The survey facilitated the identification and later evaluation of different points of interest in the Foodmicrosystems project. Efforts were made to ensure the answers were as specific as possible to facilitate their posterior evaluation. The confidentiality of the companies was respected, given that identification was not obligatory. The survey used is included in the annex.
The surveys of the two profiles ("producers" and "non-producers") were designed slightly differently.

3. Results

Around 100 people attended the meeting where the workshop was held.
At the end of the event, eleven surveys were handed in by "non-producers" and six by "producers".
The workshop was attended by producers of different sizes (large, middle-sized and small). In the group of 'non-producers, there were university research groups (devices and systems, chemical and oenological analysis), engineering for the monitoring of processes, a certification company, a public health agency, and a supplier of oenological products.
The results derive from their contributions.
Contact details were also collected from the participants who were interested in receiving information about the Foodmicrosystems project.
An aggregate summary of the responses is presented below.

4. Discussion of the results obtained

4.1. Production:

Regarding the product, 100% of the producers surveyed make red and white wine, 83% rosé wine and 66%, cava.

4.2. Innovation:

The perception of the degree of innovation in the wine world was 'high' for 40% and 'medium' for 60%. Nobody considered it 'low'

4.3. Measurement scenario:

Regarding where measurements are done, 100% of the producers surveyed have a laboratory on their installations, although they all resort to external laboratories to complement their measurements. However, only 66% have any automatic or semiautomatic measuring equipment. The proportion of those who do some kind of on-line measurement during the elaboration process is also 66%.

4.4. Interest in improvement:

On a scale from 1 to 3, the control of the process, the quality, and the safety of the product gave rise to the same degree of interest regarding their improvement (2.1, 1.9 and 2.2 respectively). The producers tended slightly more for the safety, and the non-producers for control of processes. (Still, the only measurement scenario proposed by the producers was for detecting foreign bodies in the bottles, while the majority of 'chemical' safety parameters were proposed by the non-producers)

4.5 Reasons for improving the measurements:

100% of those surveyed indicated the increase in frequency of measurements as a target for improving the measurements carried out currently. 83% opted to increase the volume of measurements, and a similar percentage to do so on-line. 66% found it interesting to improve the resolution of the measurements and only 50% would seek a greater independence from an external laboratory.

4.6. Constraining factors for application:

Regarding the constraining factors for accepting a new technology, those surveyed expressed their priorities as follows (score from 1 to 3):
Reliability (2.6) - cost (2.4) - robustness (2.1) – ease of use (2.1) – simple maintenance (1.8)
Curiously, the producers prioritised both cost (2.8) and reliability (2.8) over other considerations (1.8-1.6), and the non-producers gave priority to reliability (2.4) and ease of use (2.3) over cost (2.1)

4.7. Measurement parameters that require improvement in the elaboration of the product:

- On-line control of the fermentation (alcoholic and malolactic), automatic measurement of density, sugar on-line, faster total sugars, ensure fermentation in the bottle (for cava), sulphide/mercaptans

- Free SO2 on-line
- NH4+ and ammonium in the most
- Counting of viable yeasts
- Detection foreign bodies in the bottles
- Control of the pressure in the bottle
- O2 in the bottles
- Potential redox in the bottles
- Organoleptic objectivity
- Monitoring indicators of the authenticity of the wine
- Multiresidues in the wine, ochratoxin, fumonisin, aflatoxin, biogenic amines, heavy metals, histamine, lactic bacteria, prevention of volatile phenols,
- Concentration of sugar both during fermentation and in the circulation tanks. Quantify the level of sugar continuously
- Gluconic acid: indicator of the state of the grapes

5.8. Other requirements beyond elaboration:

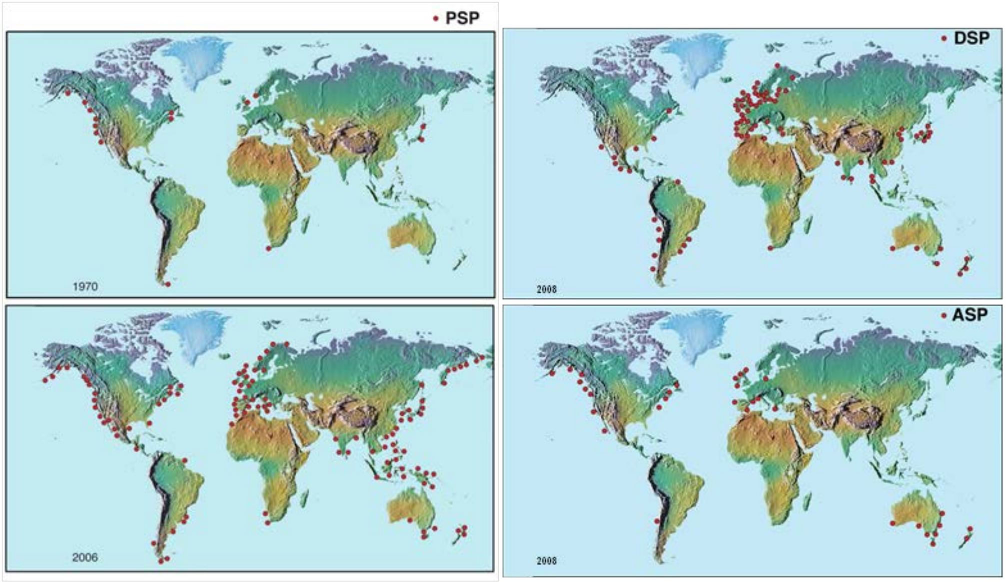
- Precision viticulture
- Grape classification (quality/state) on entry to the cellar
- Quality corks (TCA) on line for non destructive method
- Quality of the bottles
- Filtering, clarification
- On-line control of cleaning, saving of water in the process
- Traceability with knowledge of the environmental conditions
- Sensor integrated into the label to measure the temperature, light, humidity and guarantee traceability
- Resistance sensor in the package before bottling

5. Conclusions

Different actors and themes were identified both at the production level and the level of equipment supply that will be of interest in the design of the roadmap.
Safety in the production process, time and cost are important factors, as is the reliability of the measurements.
There is thus margin for the research and innovation in new fast analysis methods for different parameters in the laboratory, in-situ at the reception of the raw materials and for the development of on-line detection systems that could lead to a ‘intelligent tanks’, ‘intelligent corks’ and ‘intelligent labels’.
For the future, it would be worth going in depth into this information and determining the conditions for the different applications in function of the size of the producer and analyse what technological possibilities are available and the timeline that would be reasonable for their development.

6.8 Annex 8: Seafood sector

Red tide is a common term used for a harmful algal bloom, HABs. This bloom, like many HABs, is caused by microscopic algae that produce toxins that kill fish and make shellfish dangerous to eat. This naturally occurring event has taken place **around the world** for centuries causing a variety of negative impacts in the human health, the wildlife, the ecosystems and freshwater quality, giving rise to more fisheries resources impacted and higher economic losses. Recent water samples show increasing levels of red tide on several area beaches around of world[16].



Global distribution of PSP toxins recorded as of 1970-2006 and DSP and ASP toxins in 2008

Paralytic Shellfish Poisoning (PSP) - This disease is caused by the production of saxitoxin by the *Alexandrium* species. It is common along the Atlantic and Pacific coasts in the US and Canada**.**

Diarrhetic Shellfish Poisoning (DSP) - This disease is caused by the *Dinophysis* species. It generally occurs in Japan and Europe, but it has also been found in other countries such as Canada, the US, Chile, New Zealand, and Thailand.

Amnesic Shellfish Poisoning (ASP) - This disease, which has been found along the eastern Canadian coast, is caused by domoic acid.

Typically, the Mouse BioAssay (MBA) is a method widely used in many laboratories for analysis of marine biotoxins together with chromatographic (UPLC-MS) one[17] to validate the accuracy of the results in the analysis. However, the MBA will be banned from December 2014 by the amending Regulation (EC) Nº 2074/2005 of 10th January 2011. Based on this regulation, and the difficulty to obtain reference materials of biotoxins to can compare the accuracy obtained in the analysis, new

[16] http://www.whoi.edu/redtide/page.do?pid=14899

[17] Agencia Española de Seguridad Alimentaria (AESAN) http://www.aesan.msssi.gob.es/CRLMB/docs/docs/metodos_analiticos_de_desarrollo/EURLMB_SOP_Domoic_acid__UPLC-MS.pdf

alternative methods are required for accuracy and fast detection of biotoxins in aquatic environment and in shellfish samples.

On the other hand, the biotoxins are rare and difficult to acquire for research work and, when is available, they are very expensive. The commercial products are often questionable purity and stability and they are available in very small amounts, doing very difficult its handling (weighting accurately or safely)[18] [3]

1 Needs and demands

1.1 Safety and hygiene

Fish farmers are looking for fast detection method with the developing of a miniaturized (bio)sensor device, in order to establish a portable and cheap tool for rapid and sensitive detection assay of biotoxins content in mollusks and freshwater. Multi-toxin methods (arrays) are most desirable for a laboratory that must provide comprehensive monitoring of a wide range of biotoxins.

The touristic industry needs a remote control method as tool to detect the red tide before that it causes problems and to prevent the quality of life impacts (i.e. quality of beach activities, water recreation and fishing experience). This research can be led to new sensors to detect biotoxins in the wild and monitor its movements in the ocean.

Finally, cooking the shellfish does not destroy the toxin and there is no antidote for PSP, ASP or DSP. This is why it's so important to call to health care provider as soon as possible if any symptoms appeared. The only treatment for severe cases is the use of life support systems until the toxin passes from human system. Then, the hospitals and medical centers need the development of antidotes for quick treatment of the disease caused for biotoxins in human.

1.2 Quality control

Development of rapid specific assays and chemical analysis methods for replacement of the MBA is needed. The innovative system with real-time readings must remain easy to use to be adopted by the own fisherman, using transportable or wireless Biotoxins Microsystems (like the glucose sensor for diabetic patients).

The challenges to reach in the quality control of biotoxins can be resumed as follow:

1. To get pure Biotoxin Standards
2. To provide simultaneous monitoring for a large number of regulated toxins
3. To detect and identify toxins at low levels before they cause problems
4. Readily available Certified Reference Materials (CRMs) are therefore essential to the full implementation of microsystem chemical analytical methods
5. Robust, disposable and cheap devices had to be established in order to monitor the quality of shellfish and freshwater in real time and to perform accurate quantification
6. To find the antidotes against to any of biotoxins family group.

[18] http://curem.iaea.org/Berm13Pres/25_June/Parallel_Session_1.2/BERM13_143_Quilliam.pdf

1.3 Other issues

Other long-term goals to be considered are in relationship to performance factors of the miniaturized (bio)sensor device (i.e. precision, working life-time, sensitivity range, speed…)

2 Constraints for implementing microsystems

As in other food and environmental sectors that are included in this Report, i.e. the same requirements than in meat sector.