FOOD MICRO SYSTEMS

PROJECT FINAL REPORT

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Coordinator ACTIA

SEVENTH FRAMEWORK PROGRAMME

1 Executive summary

Microsystems have the potential to provide a wide range of technological solutions for the food industry. Micro and Smart Systems are miniaturised devices that can allow for example in situ, non-invasive, fast and automatic measurements. They can enable the building of multi-sensing platforms and use less sample and reagents. Their small size also allows low consumption of energy and enables them, unlike traditional laboratory equipment, to be distributed in space and time. Despite this interesting potential, only a few applications have been developed so far. The objective of the FP7 project *FoodMicroSystems* was to improve this situation by promoting the implementation of smart systems in the food industry.

The project started in September 2011 and ended in November 2013. The methodology is based in four main steps: (1) establishment of a knowledge base with the identification of major research players and research projects, (2) analysis of the offer with the identification of technological solutions proposed by microsystems developers, (3) analysis of the demand with the study of the needs and constraints for implementing microsystems in the food industry (industry needs, consumer acceptance, regulation constraints and ethical aspects) and (4) synthesis of the previous finding into three application roadmaps for the implementation of microsystems in the dairy, meat and beverage sectors and into one final report that provides suggestions to address the technological needs in three areas (chemical and biochemical electronic sensors, microorganism detection and tracking & tracing systems). All the reports prepared during the project are published on the public website www.foodmicrosystems.eu.

The project results demonstrate that there is strong demand from the food sector that can be met by solutions proposed by microsystems developer: applications of micro systems technologies (MST) in the food sector enable the improvement of the quality and safety of food, enhance the sustainability of the processes because of better process control, and enable product innovations that benefit consumers and society. The study indicates that the research efforts should focus on the implementation of MST solutions embedded on the production lines in the short-term, on portable devices for in-situ measurement in the medium-term and on food packaging applications in the long-term. These priorities emerged from the analysis of the regulatory framework, of the consumers' acceptance and of the environmental constraints, taking into account the maturity of the technological solutions.

The project roadmaps can be used a source of inspiration for the European Commission and National funding authorities in terms of future programmes but can also be directly used for both, industry and research organisations to define their own roadmaps and discuss collaboration strategies. The project recommends to increase research investments with the long-term ambition to allow the implementation of MST in packaging application and the short-term objectives to stimulate the adoption of MST solutions for process control at factory level. If the project identified many opportunities for further applications of MST in the food sector, it also revealed problems in the articulation of demands by the food sector that can be solved by MST, and expression of opportunities by technology companies. Further coordination of the cross-sector exchange of knowledge, ideas and research is required. The project recommends the European Commission to support such activities in Horizon 2020.

2 Summary description of project context and objectives

Context

The European food sector is the second biggest manufacturing sector in Europe with more than 300.000 companies employing around 4.3 million persons and generating an annual turnover of around 1 trillion euros. The sector is also facing several simultaneous challenges that require innovation and new technological solutions: the food industry needs to guarantee food safety, to improve the quality of the food products, to decrease its impact on the environment while continuing to provide affordable food supply to a growing population.

Microsystems have the potential to provide a wide range of technological solutions for the food industry. Micro and Smart Systems are miniaturised devices that can allow for example in situ, non-invasive, fast and automatic measurements. They can enable the building of multi-sensing platforms and use less sample and reagents. Their small size also allows low consumption of energy and enables them, unlike traditional laboratory equipment, to be distributed in space and time.

Despite this interesting potential, only a few applications have been developed so far. The objective of the FP7 project FoodMicroSystems was to improve this situation by promoting the implementation of smart systems in the food industry.

Objectives

The project provided an exhaustive review of the possibilities offered by micro systems to the food sector. In parallel, the needs have been identified in several food chains (meat, dairy, beverage, fruits and vegetable), the perception of the consumers and the regulatory context has been analysed. Building on these results, three technological roadmaps have been prepared. In order to facilitate exchange between the food sector and the micro system community, the project also organised a number of events in France, Germany, the Netherlands and Spain.

More specifically, the objectives included:

(1) The collection of information on existing microsystems applications in the food sector: funding programmes, research projects, research actors, existing applications and other initiatives.
(2) The preparation of an inventory of the technological opportunities offered by microsystem research.
(3) The preparation of a study on the needs and constraints of the food industry, of a study on consumer perception, on regulatory aspects and on ethical issues.
(4) The preparation of three roadmaps.
(5) The dissemination of the project results through a website and events.

3 Description of the main S&T results/foregrounds

The main achievements of the project include:

1. Two reports describing the state of play of microsystems in the food sector.
2. A report describing the microsystems technological opportunities for the food sector based on desk research and on an expert workshop organised in May 2012.
3. One report on the needs of the food industry, two reports describing the consumer perception on the utilisation of microsystems in the food sector, one report on the ethical aspects, one on the regulatory framework related to the implementation of microsystems in the food sector as well as synthesis report on the needs and constraints for implementing microsystems in the food sector.
4. Three roadmaps for the implementation of microsystems in the dairy, meat and beverage sectors and one final report that provides suggestions to address the technological needs in three areas (chemical and biochemical electronic sensors, microorganism detection and tracking & tracing systems).
5. A website dedicated to microsystem research in the food sector with a directory of industry and research actors and a dozen of events gathering stakeholders interested in the utilisation of microsystems in the food sector (WP5).

Key findings from the project

The Food sector is an important pillar in the European economy, as one of the most successful and dynamic business sectors. With more than 270.000 companies, it represents a significant market for developers of microsystems solutions. Microsystem technologies can help the food sector to address its key challenges (safety, quality, authenticity and optimise the use of resources) and there is a strong demand for technological innovation. Also from the consumer side there is a clear demand for information on the quality, composition and origin of the food products.

The main demands are for food product quality and safety assessment and food process control. These areas of applications combine favourable indicators in all the dimensions of the study: there is a strong demand expressed from the industry, consumers recognise the benefits and are ready to accept the implementation of such systems, and legislative provisions are already in place to regulate the utilisation of microsystems in such applications. For a successful implementation of such systems, the innovative solutions should be easily implemented in the current management practices of the food industry, the economic benefit of their use should be clearly demonstrated and sufficient considerations should be given to limit the impact on the environment at the time of the disposal of the device. Development of such systems by technology providers should be done in close collaboration with food industry partners to ensure compatibility with food processes and hygienic procedures.

There is a demand for microsystems in active and intelligent packaging but there are more constraints than for product and process control: consumers are not inclined to pay extra costs for the package, the legislative framework is more constraining (the innovative packaging needs to be approved by the EFSA) and there are concerns about the environmental impact linked to the disposal of the packaging, especially if it ends up in nature.

It is expected that the industry demand will be reinforced in the coming years, in particular for the control of food products and processes. Food safety will continue to be a priority of the food sector and the need for control of authenticity is increasing under the pressure of recent food scandals. The input prices (raw materials but also water and energy) are expected to increase in the coming years and the EU food industry will need solutions to optimise the use of resources. In this context, the demand for more sustainable processes and sensing systems allowing to better control of processes, including cleaning operations is likely to increase in the coming years.

Regarding consumer perception, the current reserves regarding the utilisation of technologies in packaging application may evolve positively. The observed trend towards convenience, health and quality could be served by packaging technologies although it is not clear whether the trend towards "authenticity and natural foods" is at odds with the benefits delivered by these high tech solutions. For example, there indications in the literature that consumers perceive plastic wrapped cucumbers as less natural and less sustainable in spite of the fact that the reduced spoilage compensates for the little amount of plastic needed. Thus the specific perceptions and relation to trends of high-tech packaging approaches deserves considerable attention.

There are definitive opportunities for applications of microsystems in the food sector offering benefits to consumers, the society and both the food industry and the technology providers. Microsystems can contribute to make our food safer, of better quality, and provide solutions that can contribute to convenience, shelf life and freshness. They can make the sector more sustainable, provide opportunities for product innovations and improve the competitiveness.

The *FoodMicroSystems* roadmaps for the implementation of microsystems in the dairy industry, in the meat industry, in the beverage industry provide detailed plans for the development of the most promising microsystems applications for the food sector. The main

On the short and medium-term, *FoodMicroSystems* recommends to focus the research effort on process control applications. Priority should be given to research in the areas of (1) miniaturisation, automation and multi-parametric to enable at-line punctual analysis offering a competitive cost per parameter when compared with current analytical alternatives (2) stability, robustness and autonomy to enable in-line/on-line continuous monitoring and (3) communications capabilities to integrate the innovative solutions in existing process management systems.

On the longer-term, *FoodMicroSystems* recommends to support research for packaging applications. Due to high economical and environmental pressure, smart devices integrated in packages should rely on cheap markers e.g printed electronic systems with a comparable cost target as ink printed markers, biomarkers, low cost electronics using no battery or emergent low cost batteries built on flexible substrates as well as newly emerged biodegradable electronics. New microsystems e.g. molecular or biodegradable markers, electronic on flexible foils, smart skins bring technologies that will allow a much more massive use of low cost micro-systems while preserving environment. Some emergent prototypes already open the path to such very low cost solution: for example, conductive optically transparent electrodes for spectro-electrochemical devices can be used to detect toxins or pathogens. Portable bio-sensing devices based on genetically engineered bioluminescent cells are also emerging slowly. Beyond 2020, the development of low-cost micro-systems will be driven by technological innovation and will meet the same goal than all other industry sectors interested in disposable testing sets.

4 Potential impact and main dissemination activities and exploitation of results

Exploitation of the project results

The project delivered a set of usable instruments, such as the roadmaps, which are based on current knowledge. These roadmaps describe ideas for future developments and they will be hopefully be used as stepping stones in future innovative research programmes. They also constitute a methodology for designing research programmes and projects: the roadmaps must be seen as a tool and the *FoodMicroSystems* consortium encourage researchers and policy makers to update and adapt them in the future.

There are a number of remaining barriers to take up MST in food applications related for example to the compatibility of the new solutions with food processes, the robustness of the devices, time to process information and provide results or the sampling strategy (how many measures, when, where etc.). Research projects where the food industry plays a major role can help to address these barriers.

Several types of future projects are needed to boost the implementation of MST in the food sector: in the short-term innovative projects focused on process control are recommended while in the long-term perspective basic research on emerging areas such as battery-less and biodegradable electronics are needed to support the development of application for food packaging. For applications in intelligent packaging, it is indeed important to underline that the innovations should not add to electronics waste and instead must be fully recyclable or biodegradable. These conditions should be met before implementing active and intelligent labels in food packaging.

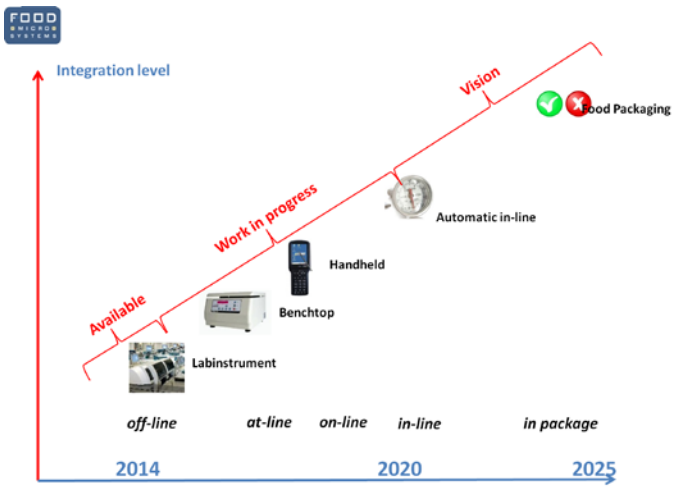
Ethical aspects related to the implementation of MST in the food sector have been considered in the FoodMicroSystems project. It reveals that the main concerns are related to safety issues and environmental issues. A clear regulatory frame concerning allowable safety issues is needed, transparency about the application of microsystems should be facilitated and the effects of product waste and disposal into nature should be considered with great attention.

Recommendations: how to use FoodMicrosystems results

The *FoodMicroSystems* roadmaps contain a lot of information that will provide ideas to decision-makers (for designing future research programmes) and to companies (for programming future developments). The partners of the project encourage companies and research organisations to use the roadmaps as a tool for planning their future activities.

Recommendations for policy makers

FoodMicroSystems encourage policy-makers to support innovation projects dedicated to the development of solution for process control in the short-term and research project dedicated to applications in packaging applications in the long-term. The roadmaps provides ideas on the topics that could be supported in these different areas.



In addition, public action is needed to support the demand for microsystems in the food sector: the food industry and developers of microsystems come from two remote areas and there is a need to stimulate collaboration and the exchange of information between the microsystem solution providers and the food sector. Without adequate support programmes, it is unlikely that the demand from the food industry will be translated into requirements understood and adopted by the microsystems developers. The project therefore recommends follow-up to stimulate information exchange between food and MST companies.

For future innovators

The first Horizon 2020calls for proposals contain opportunities of cooperation between companies and research organisation: ICT 2 – 2014: Smart System Integration ; ICT 28 – 2015: Cross-cutting ICT KETs ; SPIRE 1 – 2014: Integrated Process Control. Entrepreneurs and scientists should now seize the opportunity offered by Horizon 2020. They are also encouraged to use the roadmapping approach implemented in FoodMicroSystems as a tool for designing their future development and research programmes.

5 Address of the project public website and contact details.

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