Food Microsystems CSA-ICT-FP7

Project Objectives:

- Analysis of the Microsystems use/development in/for the agrofood sector
- Defining future perspectives and roadmaps
Food Industry challenges

Quality and safety management
Agile & efficient production
Reduced environmental impact

The food industry needs to guarantee food safety, improve process control and the quality of the food products, and decrease its impact on the environment (optimize raw material use and minimize waste) while continuing to provide affordable food supply to a growing population.

Microsystems Innovations

Continuous on line/in line non-contact process control systems (e.g. micro-spectrometers, gas sensor systems). They may further derive into handheld devices for professionals or even for consumers (e.g. smartphone).

Biosensing systems for in-situ punctual fast chemical and biological sensing. A combination of this and the previous approach may derive to smart tags-active packaging (energy and material issues to be solved).

Autonomous physical-chemical wireless sensor networks for on-field environmental control.
Miniaturised Physical–Chemical-Biological Systems for food/beverage processing, process control and environmental sustainability

Food industry is a traditional and conservative industry mostly dealing with low margin/commodity products reluctant to take a proactive role in new technologies that have no fast ROI.

It worries about reliability (or perception of such) of any new technology and it has a lack of MNT/MEMS/SSI awareness.
Definition of MST for Food

- The FMS area is microsystems (MST) with application in the food sector.
- Microsystems are defined as systems that provide information on food products or change the properties of food products and involve component build with micro and nano technologies. It focuses on material / device / equipment developments that could be regarded as an ICT contribution to food applications.
- We do not cover ingredients or additives in the food.
MST: From a chip… to an instrument

Main Microsystems areas of use

- Food safety (pathogens, pesticides, mycotoxins, fungi, antibiotic contamination,…).
- Food quality (freshness, ripeness, sugar content, taste, size, colour, odour…).
- Logistics and traceability (transport, storage,…)
- Food production control (improving efficiency, on-line, in-line control…)
- …and development of novel functional and nutritional foods:
  - Filtration / fractionation
  - Emulsification / encapsulation
  - Surface modification
Foodchain monitoring and traceability: safety and quality assessment stages

Farmers → Industrials → Retailers → Consumers

- Recollection
- Transport (transforming, poisoning)
- Processing
- Storage (active-evolving, degrading)
- Transport
- Storage (degrading)

Safety and Quality Assessment with M&NT

MST contribution: closeness to the foodstuff & power of analysis & speed
(multisensing, multipoint sensing, continuous monitoring, automation/non-specialist intervention)

to eat, or not to eat.

FMS Survey: First commercial Products

- Industrial Products
  - Packaging, 4%
  - Biosensors, 21%
  - mFluidics, 14%
  - Optical Sensors, 11%
- RFID Sensors, 18%
- Physical Sensors, 14%
- MEMS devices, 7%
- Plastic Electronics, 4%
- Chemical Sensors, 7%
European Research on MST for Food Technologies

- Biosensors, Microfluidics and RFIDs are the more studied in Europe.
- Also Flexible electronics and physical and chemical sensors.

Food Sectors in FP6 & FP7 MST R&D

- Dairy and fruits, beverages and vegetables are the main food sectors, followed by meat
Applications in FP6 & FP7 R&D

Some conclusions from FMS study

- Up to now, only logistics and traceability with RFID cards with integrated sensors is a potential mass market application.

- Some products are already on the market but with a cost that is not yet low enough.

- Other niche markets, especially for food safety and quality that are addressed with optical and bio-sensing solutions, but big commercial success has not yet been achieved.

- Food process control, can help on assuring safety and quality but also on optimising the production.
Microstructures & microdevices & microsystems

- Passive Microdevices (membranes, microsieves)
- Physical sensors
- Biosensors, DNA-chips
- Chemical Sensors / e-noses, e-tongues / Microchromatographs

Microstructures & microdevices & microsystems

- Optical Sensors / Microspectrometers
- Microfluidics / Lab-on-a-chip
- Printed electronics
- RFIDs / Wireless Sensor Networks
Some Conclusions of FMS survey

• Looking for MST solutions that both can compete with laboratory systems but also that can complement them.
• Current use of other non MST or standard laboratory solutions is still valid when small size is not a must.
• MST are looking for improving the stability and reliability of biosensors, as it is still an issue for on-line and in-line deployments.
• Regulations (samples of 25 g.) may be an issue for MNT based solutions, but they also create new regulations, and also be used for screening.

Summary: Applications/Sectors/Technologies

Applications
• safety
• quality
• process control
• logistics
• traceability

Food Sectors
• Meat
• fish
• dairy
• fruit
• vegetables
• beverage

MNT Tech.
• RFID & sensors
• WirelessSensorNets
• flexible electronics
• microfluidics/LoC
• physical sensors
• chemical sensors
• e-nose/e-tongue
• biosensors /DNA
• optical sensors (non bio)
• MEMS evices
• Other....
Some Commercial Examples

RFIDS + Sensors

Monitoring cold chain of perishable products
Time/temperature indicators

Pathogen detection
Examples of commercial products

InBea Bioensors

Quality control in wine, beer, fruit juices, milk,…

Determination of glucose, fructose, ethanol, L-malic, L-lactic and gluconic acids,…

Packaging: Ripeness

This pear is red. crisp

This one’s orange. firm

And this one’s yellow. juicy

To find your perfect pear, just look for the ripeSense® sensor.

www.ripesense.com
Quality control

Colour control with Microspectrometers

Separation / Fractionation

Cees van Rijn – Aquamarijn
Membrane emulsification

- Ingredient water purity
- Water use optimization
- Process efficiency
- Effective wastewater treatment
Roadmap methodology and first results

1. State of the art in R&D and on the market
2. Needs & Priorities
3. Needed capabilities
4. List of technology goals to be roadmapped
5. Determine technology readiness levels & key performance indicators
6. Estimate timelines
7. Roadmap
Main drivers dairy innovations

From a consumer perspective:
2. Quality, authenticity, health etc.

From an industry perspective:
1. Efficient usage of resources.
2. Reduction of waste.
3. Detection of unwanted content.
4. Profiling etc.
Of interest for the dairy industry

1. Measurements during the dairy processing (on-line, in-line, off-line)
2. From cow to raw milk (measuring quality, contamination)
3. Quality control (analysis of final dairy product)
4. Specific sensors / analysis for liquid dairy products (e.g. yoghurt, milk)
5. Specific sensors / analysis for creamy to solid airy products (e.g. cheese, butter, cream)

Q: Can we define specifications for them and identify state of the art on the market and in R&D?

Measurements during the dairy processing

• Specifically:
  – pH
  – Cleanliness: thickness and characterization of biofilm, residue of cleaning materials, milkstone
  – Pathogens (draft roadmap in next sheets)
  – Herbicides
  – Pesticides
  – Antibiotics
  – Dioxins / PCBs
  – Allegens
  – Detergents
  – Mycotoxins
  – Heavy metals
  – Other?

Decisive factors: cost and time to result?

Priorities? State of the art?
Pathogen detection: comments on Technology Readiness Level

- Performance indicators:
  - ease of use,
  - Sensitivity,
  - Cost of test,
  - time to result.
- Key technologies: sample treatment and biosensor.
- State of the art sample treatment unit
  - Extraction of fluidic sample from solid sample: lab instrument only, bench top and portable system in research
  - Lysing unit: bench top, < 15 minutes for R&D work
- Much work is being done in pathogen detection for medical diagnostics and environmental testing. Several small, fast systems are in development. Practically all these systems deal with liquid samples.
- It is therefore expected that the testing on pathogens in liquid food will first come to the market.
Detection of pathogens

Sensitivity

ng/ml

pg/ml

Available

Lab instrument, < 24 hr, expert specialists

Work in progress

Module

Integration level

Component

Chip

No amplification needed

Compact sample treatment module

Handheld, <10 min, inline operators

Automatic in line & less than 1 sec

No sample treatment

Offline

Online

Inline

2010 2015 2020 2025

Technology roadmap pathogen detection

- Step 1: PCR, concentrating, labeling and fluorescence detection.
- Step 2: PCR, concentrating, direct detection with biosensor.
- Step 3: Concentrating, detection with biosensor.
- Step 4: direct detection with biosensor.
- Comments:
  - Decisive factors: cost and time to result.
  - PCR is only suited for offline control due to the inherent complexity and the slowness of this method (high equipment costs only affordable for massive parallel testing).
New processing technologies

• There have been made huge steps in the development and understanding of the emulsification and encapsulation processes, but the problem of affordable manufacturing in large volumes is still not solved.
• Energy efficient processing: cold sterilization
• Optimizing usage of ingredients: fractionation
Emulsification, drivers & barriers

• Drivers:
  – Controlled release of ingredients (pharma, agriculture, functional foods, packaging)
  – Extended shell life due to increased stability
  – Health: (low fat content)
  – Other

• Barriers:
  – Lack of cost effective reliable and high throughput processes for highly uniform emulsions.
From older food roadmaps

Commercial feasible concepts failed to emerge!

Developments in other market segments might be more successful!

Figure 1: Roadmap for microsystems in the food industry (courtesy Aquamarin)
OTHER TESTING NEEDS

Allergens detection: state of the art

- 2012: Intensive R&D for allergic testing in medical diagnostics, not so much in food industry.
- 2012: State of the art bench top: 5 ppm in 10 minutes (test tube based system).
- 2012: In research: handheld, 20 minutes (test tube based system)
- 2012: on the market; peanut allergen kit <10 minutes, ppm-ppb level, SPR based (Seattle Sensor Systems)
Mycotoxins: state of the art

- State of the art: ELISA autoanalyzer + HPLC
- In development: MiniChemLAB Microfluidic Workstation Prototype Instrument from Minifab. They demonstrated detection of Aflatoxin M1 in raw milk. Sensitivity (0 to 2000ppt), time to result < 5 minutes.

Other testing

- Physical:
  - temperature,
  - humidity (in cheese),
  - density,
  - Ph;
- Chemical:
  - characterization,
  - protein,
  - lactose,
  - dry material,
  - info about cells,
  - somatic cell content,
  - residual chemical from cleaning step,
  - fat content

Definitions:
inline is direct measurement
online is sampled but on the spot analyzed;
offline is sampled and send to a lab.

Priority:
1. knowledge about dry matter content and profiling leads to better process control & less low quality / low price products.
2. Acidification
Fouling detection

• Fixed sensors?
• Pigs? (See oil industry)

Ripeness sensors

• Sensor in package (color change). State of the art?
• Electronic nose in supply chain in research only. State of the art?
Profiling etc.

- State of the art: soluble protein content in milk within 5 minutes offline by Amaltheys (fluorescence analyzer developed by Spectralys Innovation, enables to measure milksoluble proteins and gives also an indicator of its thermal history.)
- Proposed for profiling
  - Capillary electrophoreses systems (electrolytes in liquid)
  - Chromatography
- Profiling wine (counterfeit labels), GMO and halal testing, state of the art?

Other technologies / systems needed

- Surface modification: cost? Durability? Chemical of topology?
  Many activities, not analyzed yet.
- Bioreactor for testing cheese
Summary roadmap

Pathogen detection
Emulsification
Nutraceutical
Foams
Food other
Etc.

...our roadmapping is still ongoing!
Please contact us for latest results!

Patric Salomon, patric@enablingmnt.com

Thank you for your attention!

- Patric Salomon

enablingMNT GmbH
Patric R. Salomon - Managing Director
Holsteinische Str. 23, 12161 Berlin, Germany
Phone: +49 30 24357870
E-mail: patric@enablingmnt.com
Skype: patricsalomon

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