COORDINATOR

Actia (France)

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Estonia (Tartu Biotchnoloogia Park)
France (Actia [Actilait, Adiv, Aérial, LNE], CEA, Euroquality)
Germany (4M2C, Fraunhofer)
Netherlands (DLO, University of Wageningen)
Spain (CSIC)

Microsystems Opportunities in the Food sector – first results from the FoodMicroSystems roadmapping experience

MINASENS Workshop, 8 Mar 2013

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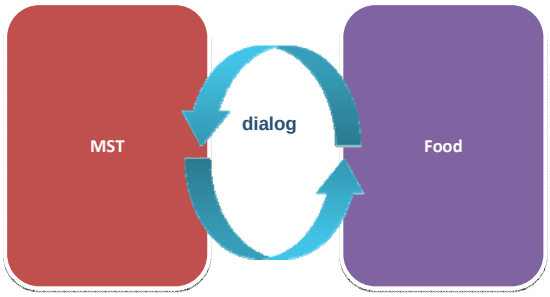
Food Microsystems CSA-ICT-FP7

Project Objectives:

✓Analysis of the microsystems use/development in/for the agrofood sector
✓Defining future perspectives and roadmaps



Food Industry challenges

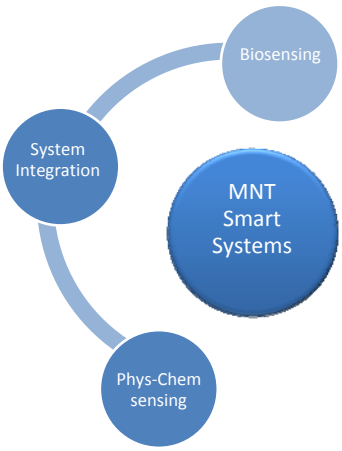
Quality and safety management

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

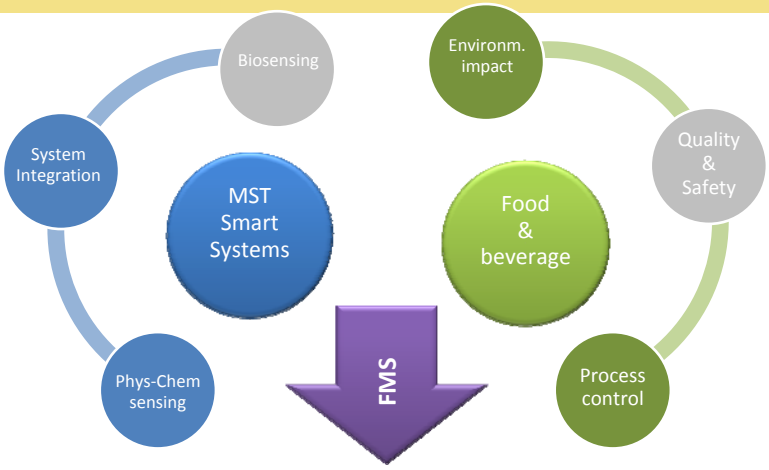


Continuous on line/ in line non-contact **process control** systems (e.g. micro-spectrometers, gas sensor systems). They may further derive into **handheld** devices for professionals or even for consumers (e.g. smartphone)

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

“MST for food”



Miniaturised Physical –Chemical-Biological Systems for food/beverage processing, process control and environmental sustainability

Facts and figures of the food & beverage sector

Turnover	Employment	SMEs[1]
€954 billion (-4.0% compared to 2008) Largest manufacturing sector in the EU (12.9%)	4.2 million people (-1.5% compared to 2008) Leading employer in the EU (13.5%)	48.2% of food and drink turnover 62.8% of food and drink employment

External trade	Number of companies	Value added (% of EU GDP)	Consumption (% of household expenditure)
Exports €53.7 billion (-8.0% compared to 2008) Imports €50.8 billion (-14.2% compared to 2008) Trade balance €3.0 billion Net exporter of food and drink products	310,000[1] Fragmented industry	2% Stable	13.1% Slight increase

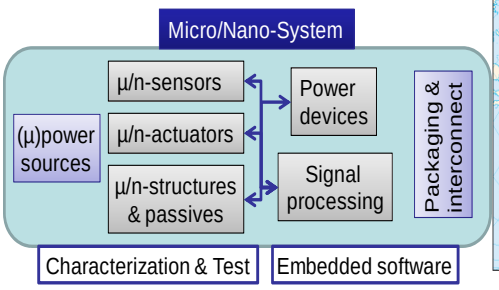
EU share of global exports	R&D (% of food and drink output)
18.6% (20.4% in 2000) Shrinking share in global exports	0.37%[2] Insufficient R&D expenditure

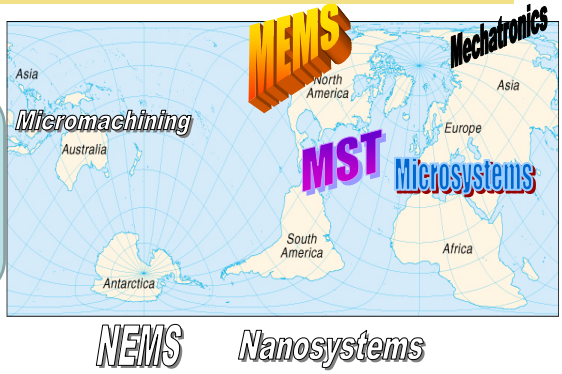
(1) 2007 data
(2) 2006 data

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,

Microsystems, MST, MEMS,...: What are they?

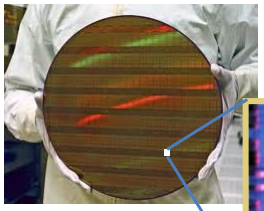




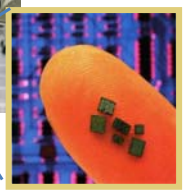
Definition of MST for Food

- *The FMS area is microsystems (MST) with application in the food sector.*
- *<u>Microsystems are defined as systems that provide information on food products or change the properties of food products</u> 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.*
- *<u>We do not cover ingredients or additives in the food.</u>*

MST: From a chip… to an instrument



wafer

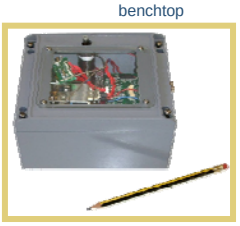


device

Component or subsystem

portable

benchtop



on-line

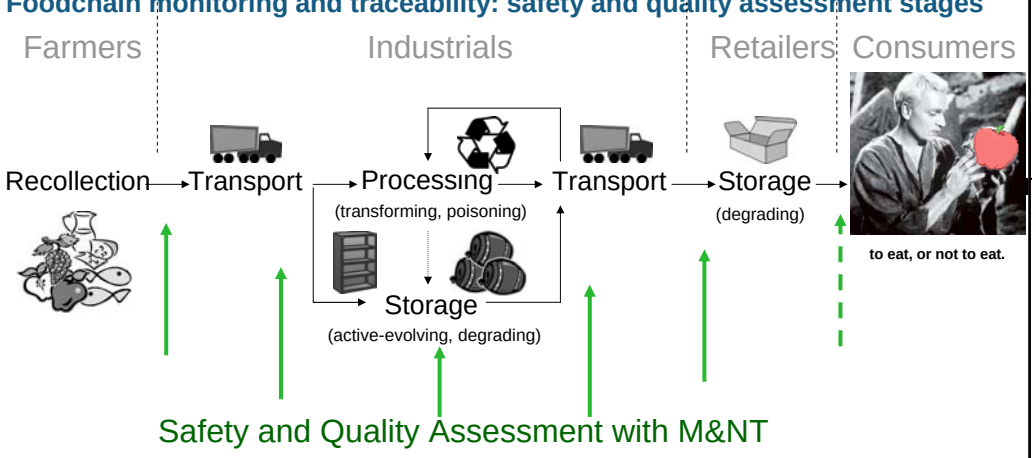
Miniaturised and cost-effective instruments

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

and where MST can be used?

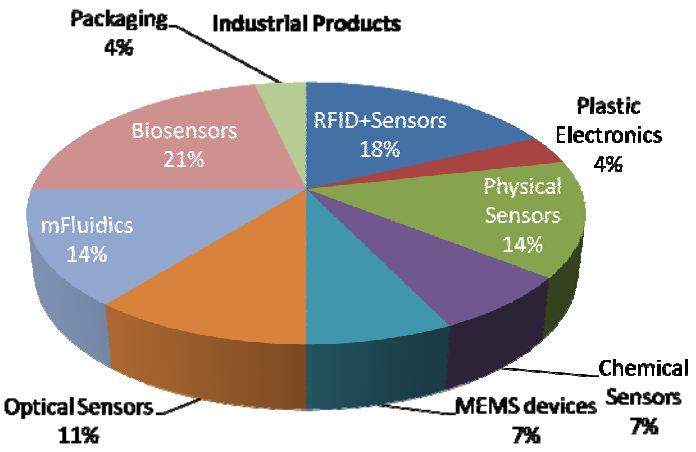
Foodchain monitoring and traceability: safety and quality assessment stages



MST contribution: closeness to the foodstuff & power of analysis & speed

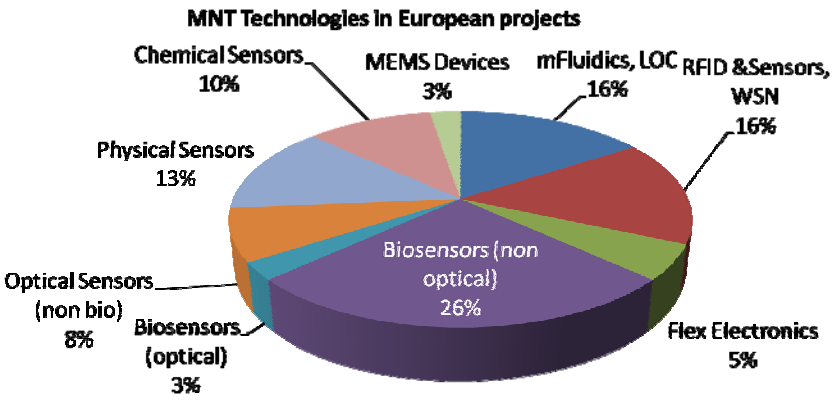
(multisensing, multipoint sensing, continuous monitoring, automation/non-specialist intervention)

FMS Survey: First commercial Products



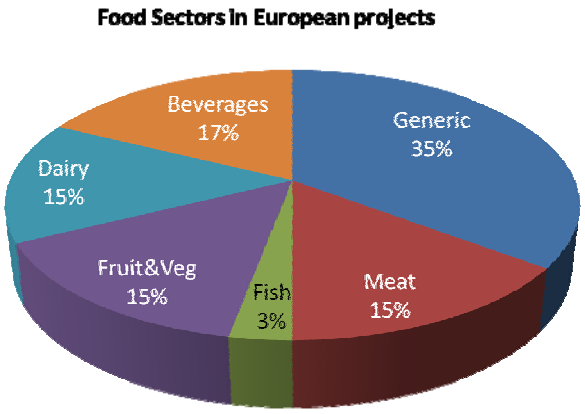
European Research on MST for Food Technologies

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

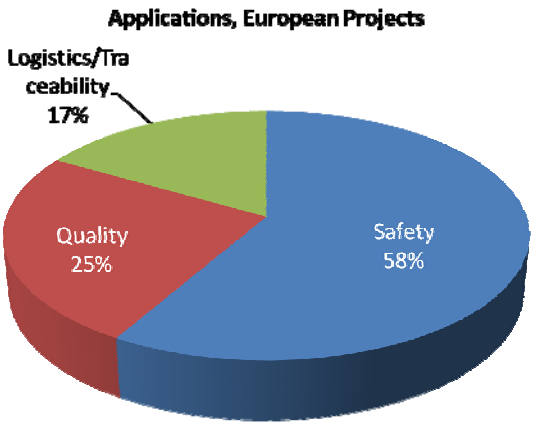


Food Sectors in FP6 & FP7 MST R&D

- Dairy and fruits, beverages and vegetables are the main food sectors, followed by meat



Applications in FP6 & FP7 R&D

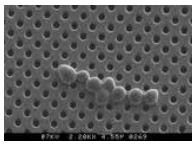


Some conclusions from FMS study

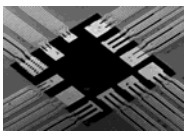
- Up to now, only logistics and traceability with RFID cards with integrated sensors is a potential mass market application.
- Some products are already on the market but with a cost that is not yet low enough.
- Other niche markets, especially for food safety and quality that are addressed with optical 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

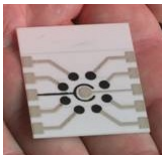
- Passive Microdevices (membranes, microsieves)

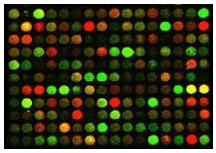


- Physical sensors

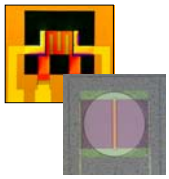


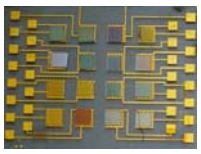
- Biosensors, DNA-chips

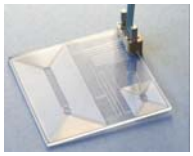




- Chemical Sensors / e-noses, e-tongues / Microchromatographs

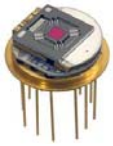


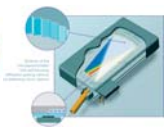




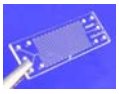
Microstructures & microdevices & microsystems

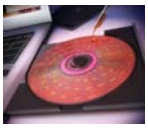
- Optical Sensors / Microspectrometers





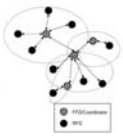
- Microfluidics / Lab-on-a-chip

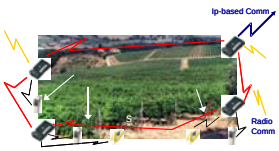




- Printed electronics

- 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	Food Sectors	MNT Tech.
• safety • quality • process control • logistics • traceability	• Meat • fish • dairy • fruit • vegetables • beverage	• 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

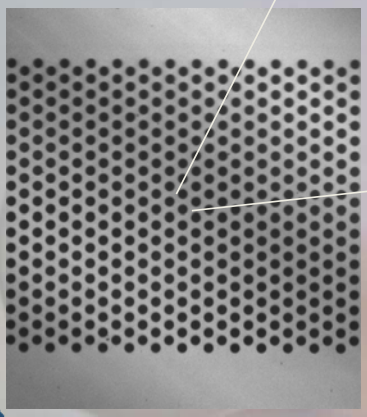
Monitoring cold chain
of perishable products

Alvin Systems

KSW MICROTEC

Time/temperature indicators

Pathogen detection



Examples of commercial products

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

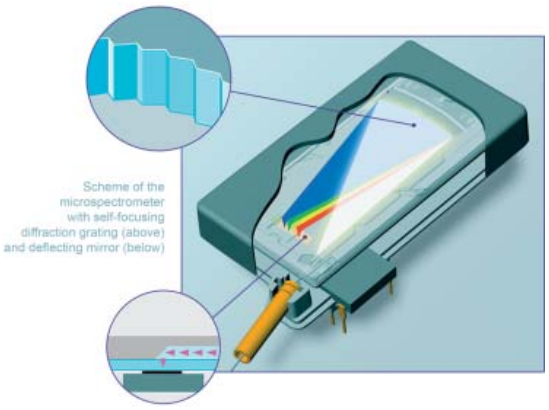
Determination of glucose, fructose, etanol, L-malic, L-lactic and gluconic acids,…

Packaging: Ripeness

www.ripesense.com

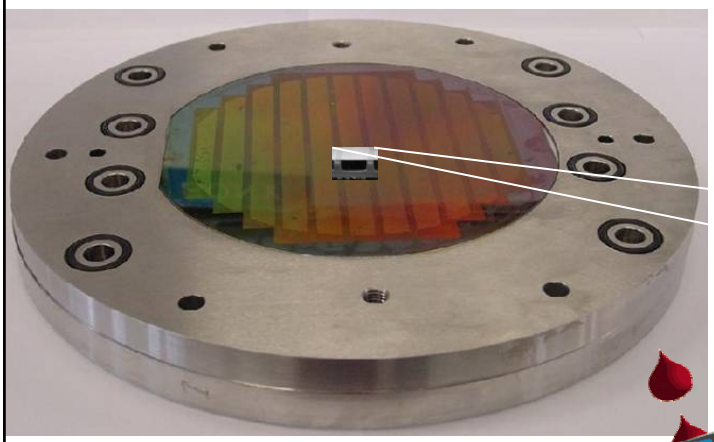
Quality control

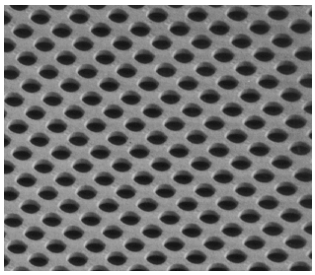
Colour control with Microspectrometers

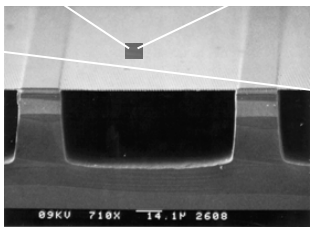


Insion GmBh

Separation / Fractionation

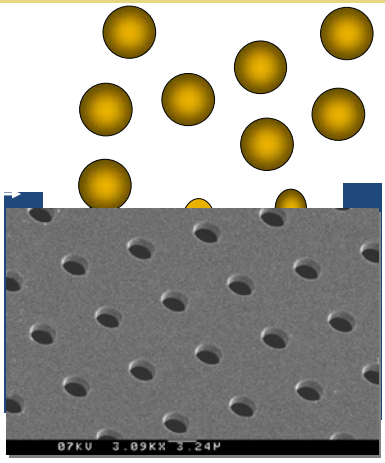


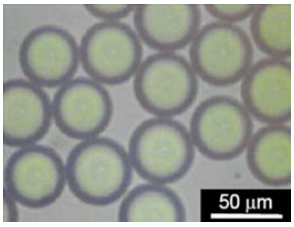


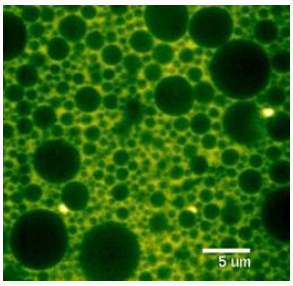


Cees van Rijn – Aquamarijn

Membrane emulsification







nanomi emulsification systems

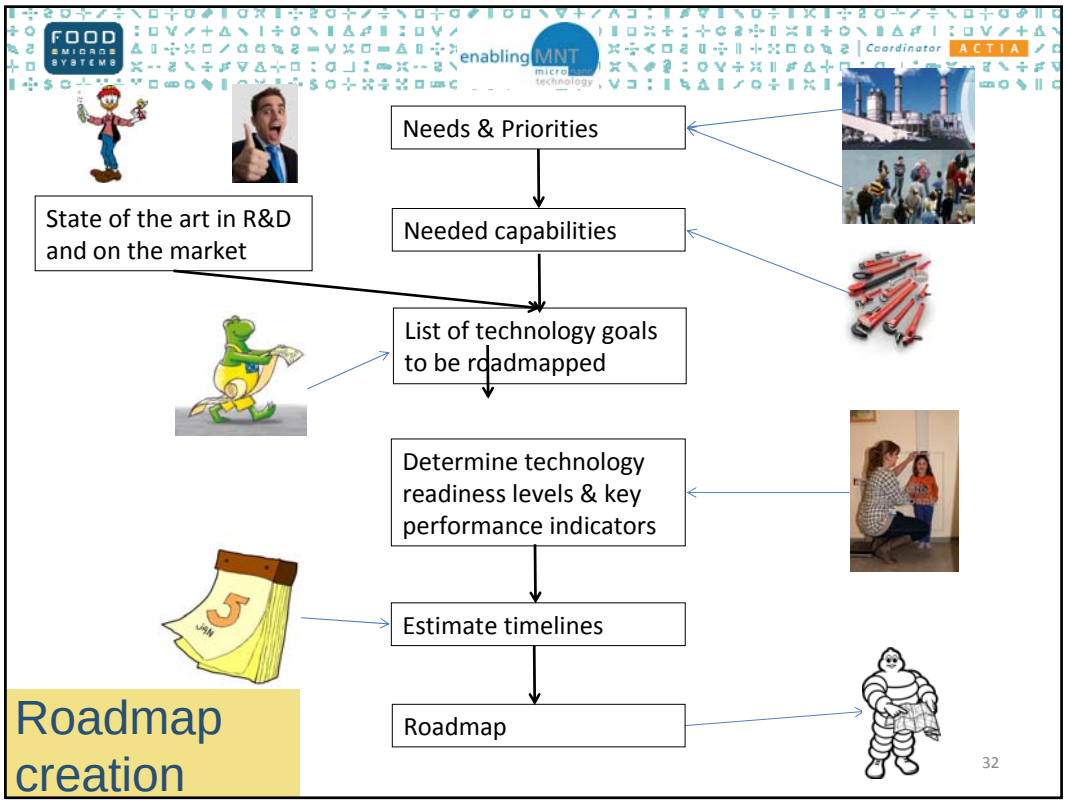
Water quality control in food processing

Chemical sensors probes

- Ingredient water purity
- Water use optimization
- Process efficiency
- Effective wastewater treatment

neosens Pure Sensor Solutions

enablingMNT / FoodMicroSystems Roadmapping Methodology and first results



Roadmap creation

Main drivers dairy innovations

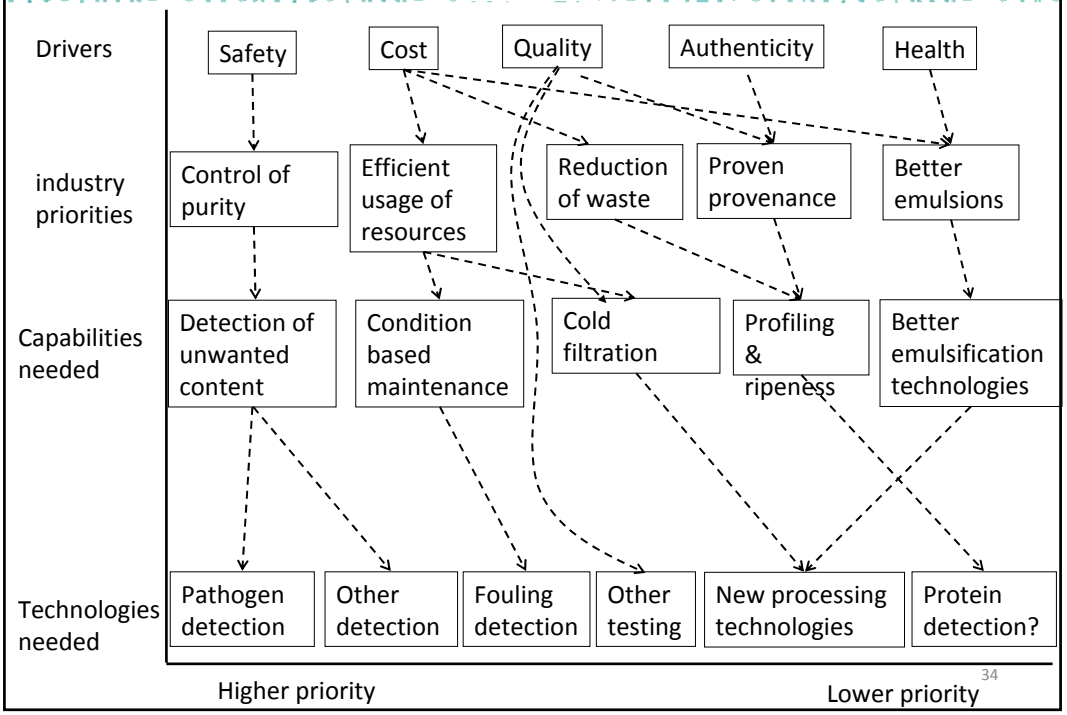
From a consumer perspective:

1. Cost & safety.
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.

Dairy technology priorities



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?

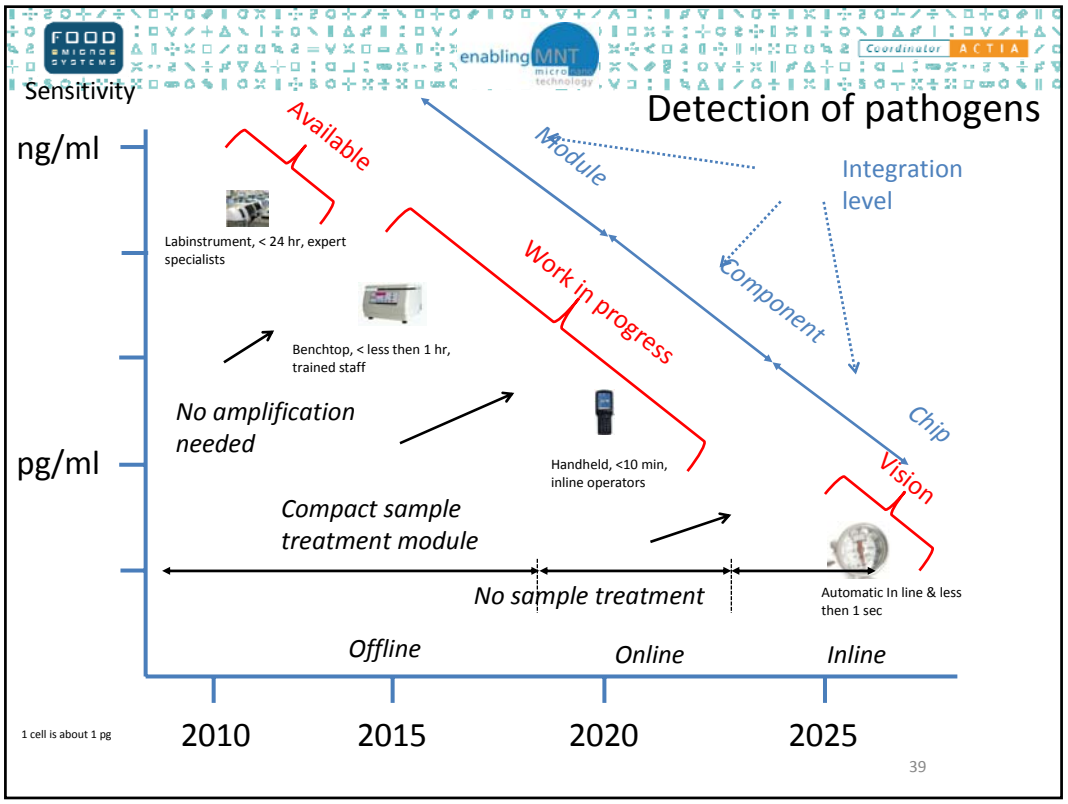
Decisive factors: cost and time to result?

Priorities? State of the art?

PATHOGEN DETECTION ROADMAP

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.



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).

EMULSIFICATION ROADMAP

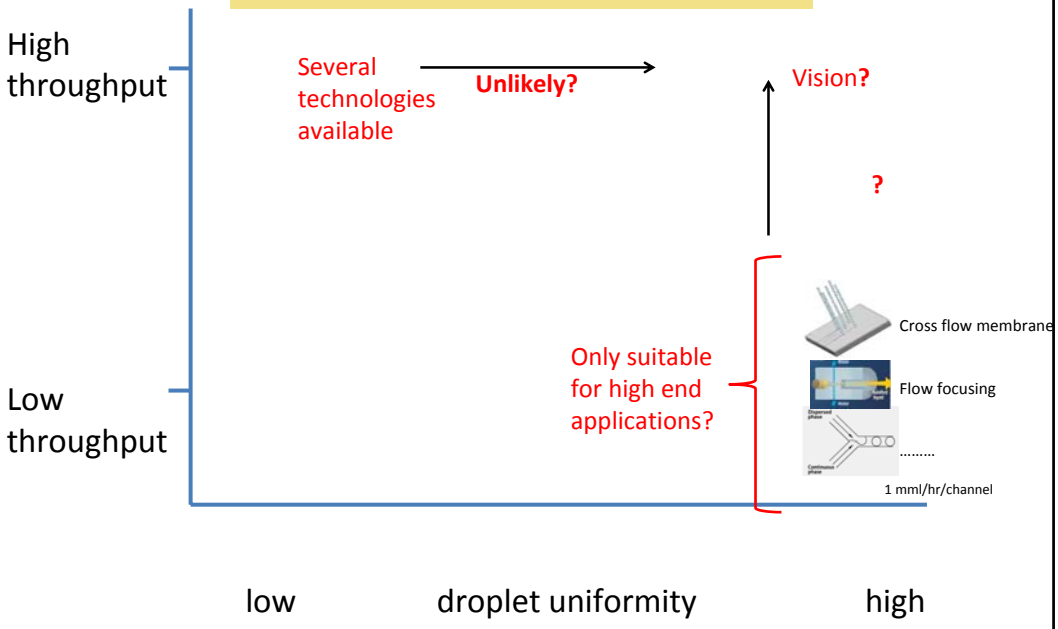
New processing technologies

- 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

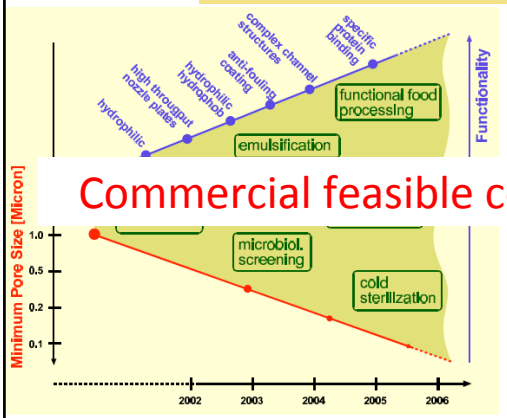
Emulsification, drivers & barriers

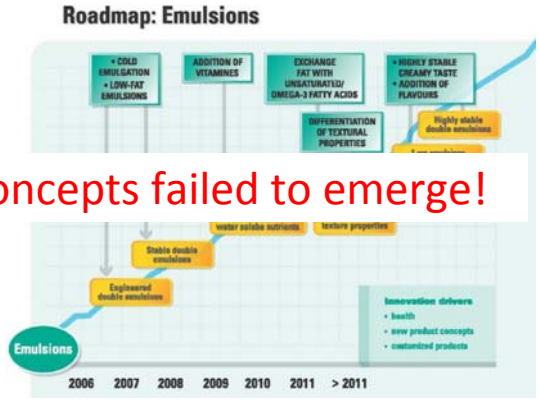
- Drivers:
  - Controlled release of ingredients (pharma, agriculture, functional foods, packaging)
  - Extended shell life due to increased stability
  - Health: (low fat content)
  - Other
- Barriers:
  - Lack of cost effective reliable and high throughput processes for highly uniform emulsions.

Emulsification



From older food roadmaps



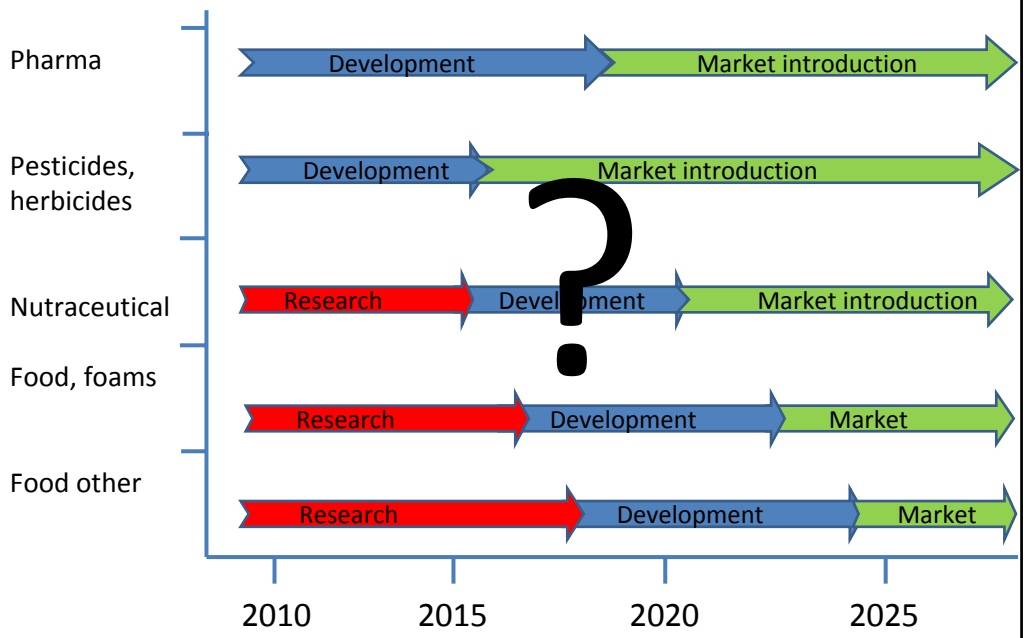


Commercial feasible concepts failed to emerge!

Developments in other market segments might be more successful!

Figure 1: Roadmap for microsystems in the food industry (courtesy Aquamarijn)

Application roadmap emulsification



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.

Market

Market

Market

...our roadmapping is still ongoing!

Please contact us for latest results!

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Thank you for your attention!

- Patric Salomon

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