Advancements in Micro & Nanotechnology and their Practical Application for In-line Monitoring


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Outline

- Introduction
- Needs from the Consumers and From the Food Demand in terms of Safety, and Quality
- In-line On-line measurement benefits
- What Sensors and Microsystems can offer?
- What else with Nano?
- Examples of In-line/On-line monitoring
- Other Commercial applications
- Conclusions
When Food and Microtechnologies meet
Food Consumers Demand: Quality and Safety

Monitoring of the Food chain

Farmers → Recollection → Transport → Processing → Transport → Storage → Retailers → Consumers

- Farmers (producers)
- Industrials (processors)
- Retailers (distributors)
- Consumers (final users)

Recollection → Transport → Processing → Transport → Storage → to eat, or not to eat...

Safety and Quality Assessment with M&NS

M&NS contribution: bring lab close to the foodstuff & power of analysis & speed (multisensing, multipoint sensing, continuous monitoring, automation/non-specialist intervention)
Food Analysis: Proximity to the sample

Impact of the Sensors and Microsystems

From: http://pubs.rsc.org/en/content/articlelanding/2017/an/c6an02608g#!divAbstract
What Micro and Nano Systems can offer?

- Many solution based on:
  - Lab analysis (costly and time consuming)
  - ‘Expert’ human intervention (subjectivity)
  - Destructive, not massive

- Micro & Nano Systems alternative:
  - Miniaturisation: dimensions, weight, power consumption, portability.
  - Cost reduction of the sensing devices and less reagents required.
  - Fast response… Prevention.
  - Electronics reading & Autonomous Functioning
  - Connectivity, Communication, Data Transfer and Management
  - Non invasive, Pervasive and ubiquitous solutions
  - New functionalities
  - Ubiquitous, Redundant, Matrixes, Multisensing
What In-line and On-line Solutions can offer?

- Continuous monitoring. Repeatability
- Can provide early alerts and prevent contaminate products
- Decreased product loss
- Enable faster response to changes in raw material quality or process drifts.
- Cleaning of filtration processes based on direct measurements
- Sorting by quality.

But:
They will never replace the high precision of lab measurements.
In-line examples

- CIP: Clean in Process: saving water usage, energy and cleaning products
- Process control:
  - Physic Parameters: Temperature monitoring, Pressure, Acceleration, Weight (load cells),
  - Chemical Parameters: Flow, pH, Humidity, Viscosity, Conductivity, Density, Brix, Salinity, Alcohol, ..
- Other: Fermentation …
- Color, defect monitoring,
- Freshness, Ripeness,…
- Monitoring of Robotic equipment
- Agro,
- Logistics,
- Storage,…
And In-line product quality: NIR

- **Product quality:**
- **Near Infra Red (NIR) 780-2500 nm:** No sample preparation, simultaneous multiple measurements.

- **Milk:** process parameters: moisture, protein, fat, lactose, ...
- **Meat:** Fat, moisture and protein content, NaCl in cured meat
- **Fruits and vegetables:** moisture, sugar content, colour, transgenic or not transgenic tomatoes ...
- **Grain and grain products:** quality grades, humidity, sugar, starch
- **Oils:** Acidity, oxidation levels, adulteration
- **Fish:** End point temperature, moisture in dried fish
- **Beverages:** Alcohol content, sugar, adulteration, fermentation control.
Food and Micro and Nanoelectronics Sensors and Systems: Can we help?

Yes we can!
What are Micro and Nano Technologies?: Integrated Circuits but also Sensors and MEMS
MEMs: Application Drivers
• Second element on the Earth surface, after oxygen
- Passive Microdevices (membranes, microsieves)

- Physical sensors: Temp, Humidity Pressure, Accelerarion, Optical,…

- Biosensors, DNA-chips Lab-on-chip

- Chemical Sensors / e-noses, e-tongues / Microchromatographs
Microstructures & microdevices & microsystems

- Optical Sensors / Microspectrometers
- Microfluidics / Lab-on-a-chip
- Printed electronics
- RFIDs / Wireless Sensor Networks
In summary: Sensors and MST in AgroFood applications

Bringing the lab to the product...

• In Food Processing
• In Food Safety
• In Food Quality and Preservation
• Logistics and Packaging
• In Nutrition and new food products

Prevent Consumer Concerns like with GMO’s: focus groups, consumer surveys

Fish and Chips, not fish with chips...
And what about nano in food?
NanoTechnology: A crossroad

Scale limit mastered by technology

Nano size: be closer to the biological media to improve specs

Biocomplicity:

- Tissues
- Cells
- Genes
- Proteins

MATERIALS

- Stone
- Wood
- Iron
- Silicon
- DNA
- Cells
- CNT
- APM
- Atoms
Nano: The importance of the SCALE FACTOR

When dimensions decrease:

- the Surface/Volume ratio increases
- the Length/Surface ratio increases
- the dynamics of thermal structures is faster
- the structures heat-up with less energy
- the structures suffer from less thermal and mechanical stresses
- the diffusion in a fluid is faster
- the evaporation is faster
- the mixture in microchannels is more difficult
- the power consumption is smaller
“Active” Applications: Surface modification of sensors in the nano domain

DNA: surface nanoestructuration for the improvement of biological material immobilisation

Nanosized materials: Increase of sensitivity due to higher surface/volume ratio

Nanoelectrodes for Immunosensors: Electric field confinement and Improved (spheric) diffusion from media to electrodes

From GoodFood Partners
“passive” nanoapplications in food

Surface to fluid interaction: surface coatings (wetting, self cleaning, antifouling, microbial free…)

Texture control, emulsification…

Separation, filtration…

Food packaging, barriers/scavenging
   Protective layers
   Anti Microbial Growth
   Anti Oxidation

Nutrient delivery, smell & flavour encapsulation…

Courtesy of Aquamarine
Examples of In-line/On-line solutions
CIP: Cleaning in Place: pH, Cond. CNM

Whole Milk Measurements
Conductivity Sensor 1406-A3-CRL

Conductivity (mS/cm)
Temperature (deg. C)

pH Sensor 1387-3-A2

pH
Temperature

CIP Clean in Place

CIP: Cleaning in Place: pH, Cond. CNM

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Temperature

CIP Clean in Place
ISFETs: pH, Ions, Temp. Conductance, …

Multiparameter Probe:
- pH
- Ions
- Conduct.
- Temp.

Robust
In-line water cleaning Monitoring

Benefits

• Real time water network monitoring
• In-line water contaminant identification
• Efficient control of water distribution

Main features

• Measurement of the main disinfection species
• No interference with chloramines
• Chemical free operation
• Annual maintenance and calibration
• Easy field installation with direct insertion in pipe,
• Battery operated
• Real time telemetry data transmission
Water quality control in food processing

Chemical sensors probes

- Ingredient water purity
- Water use optimization
- Process efficiency
- Effective wastewater treatment
NIR Spectroscopic System for milk monitoring

Inline monitoring aids in food safety and quality

What you don’t measure could kill your brand.

NIR spectroscopy and an imaging sensor make it possible for powdered milk process parameters—such as moisture, protein, fat and lactose—to be determined quickly and simultaneously using just one system, the Sartorius PMD500 NIR process analyzer. Source: Sartorius.
MEMS NDIR Systems for Milk fat and Wine fermentation

‘physical’ interaction  ex: Infrared absorption

(No sample preparation )

Each aroma/liquid one filter one signal
any vapour/liquid one multi-filter one fingerprint
Micro NIR

- IR emitter. ReflectIR P1C
- Piece 2
- Input/Output. Luer-lock
- Perforated CaF$_2$ window
- Teflon® spacer
- CaF$_2$ window
- Piece 1
- Closing system
- Thermopiles & filters. DIL40

Sample thickness 200um

Acetone
Methanol
Ethanol
Water

PC 1 (86.4 %)
PC 2 (9.87 %)

4x4 Assymmetric

day22
day23
day24
day25
day28
day29
day30
day31
Water
In-line control in Breweries:

Brewery

LiquiSonic® Plato is a high sophisticated inline analyzer for concentration and density measurement of beer and wort in breweries. The system allows control and monitoring of concentrations at different points of the brewing process.
In-line and Lab Concentration and viscosity

**COBRIX** multiparametric “on-line” Analyzer for beverages: Concentration, viscosity, CO2 density, temperature...

For beverages: the continuous, accurate and safe measurement of essential quality parameters such as °Brix, %Diet concentration, CO₂, alcohol, sugar inversion, extract, and more throughout your production process.
RFIDS + Sensors

Monitoring cold chain of perishable products

Alvin Systems
Time/temperature indicators
Quality control

Colour control with Microspectrometers

Insion GmbH
other on-line, at-line products

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

Determination of glucose, fructose, etanol, L-malic, L-lactic and gluconic acids,…
Biosensor para el análisis de Sulfito en Agua

Descripción ge

Un biosensor es un dispositivo biológico con un transductor que permite la detección de moléculas específicas. BIOLAN hace uso de la técnica de biosensores para la detección de moléculas específicas, como el sulfito en el agua. El biosensor portátil y de bolsillo de BIOFISH 700 permite controlar parámetros de interés en la calidad del pescado y/o marisco en menos de 1 minuto.

Se trata de un Biosensor portátil y de bolsillo que a través de electrodos serigrafiados te permite controlar parámetros de interés como Ácido Mático y Glucosa, en la elaboración del vino en menos de 1 minuto.

BIOWINE 700 ÁCIDO MÁLICO

BIOWINE 700 GLUCOSA
AlphaMOS: Electronic tongue system with CNM sensors

Analysis of food products such as wines, beverages and soups

Multisensor system with different optical and electrochemical and chemometric transducers

Classification approach

Quantification approach
Wine analysis: pH sensors and Biosensors: CNM

- **Acetic acid, SO$_2$:** Flow sensor approaches integrating diffusion membranes and pH detection (ISFET)
- **Lactic & malic acid:** Amperometric biosensors showing long lifetime

Thin-film enzyme biosensors with polypyrrole membrane

- Analytical performance compared with the standard analytical protocol
- Biosensors long lifetime over 45 days
E- Nose: Fish, Fruits,... vapour sensors

Freshness: DMA, TCA, NH3...

Ripeness: Ethilene

WINOSE. ITEFI CSIC
RFID Systems for Logistics: False Alarms in Cargo Planes

- **Objectives:**
  - Sensor system with RFID communication
  - Tracking and tracing of goods

- **Challenges:**
  - Power consumption of sensors, especially gas sensors
  - Reliable integration and packaging into flexible substrates
  - Vapours: Ethylene,..
Accelerometers and Vibration sensors for Machinery health, plant control

The food and drink processing sector uses a broad range of equipment in its production processes including mixers, centrifuges, pumps, motors, air compressors, ovens, fans and conveyors. In each case, equipment has to be maintained in optimum condition, requiring a proactive approach to maintenance and condition monitoring.

Vibration monitoring plays a key role, helping maintenance and plant engineers with early identification of component wear in bearings, rotating shafts, conveyors and other line equipment.
Robots in Food: Sensing motion

- Packaging
- Picking
- Production
- Harvesting robots
- Exoskeleton for working with heavy loads

Abb
Omron
Hook assist
Robots of the future: Drones

Automatic Supervision

Plant to plant actuation....

From T. Dobbs
Examples: In situ control Harveters & Tractors

Mature sensors
- Engine (FT4) ~32 sensors
- Cab ~12 sensors
- Drivetrain and chassis ~15 sensors
- Harvesting system ~40 sensors
- Total ~100 sensors

Emerging sensors
- Improved mass flow/moisture
- Grain loss/harvest quality
- Constituent (protein)
- Spout aiming
- Header control
- Knowledge-based sensing ~10 sensors

- pressure,
- acceleration
- temperature, tilt
- emissions, NoX, CO, CO2
- Turn speed,
- Ultrasounds
- Load, overload,
Ex: Wireless Sensor Networks for precision agriculture

- Energy
  - Solar
  - Batteries
  - Energy Harvesting
Ejemplo: Agrisense, Vinesense

Agricultura y Viticultura de Precisión

- Evalúa condiciones de crecimiento de patógenos.
- Ayuda a realizar efectivamente tratamientos químicos.
- Mide datos medioambientales directamente en la viña (temperatura aire/humedad relativa, humedad de las hojas, lluvia acumulada).
- Interfase vía desktop, notebook, smart phone o tablet.
Conclusions

- Increasing concern on Food Safety and Quality.
- Real need of new diagnostic systems for safety and multisensor solutions for quality and traceability.
- Many of the current available solutions in the market do not rely on electronic sensors and Microsystems.
- (bio)-MST are interesting enabling technologies as far as they improve performances and increase applications:
  - Portable, Faster, Cost reduction, Higher sensitivities and selectivities

- Nanotechnologies are interesting enabling technologies as far as they further improve sensor/system specifications.

... but we have to convince more the Food Industry on the goodness of MNT/MEMS based sensing systems.

In line/on-line is an example.....
Thank you for your attention !!!!.

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Other Commercial Examples for Different Applications
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.
Separation / Fractionation

Cees van Rijn – Aquamarijn
Membrane emulsification
Pathogen detection