DEMONSTRATION OF A RFID SMART TAG FOR TRACEABILITY OF FRESH FISH LOGISTIC CHAIN

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(AZTI-Tecnalia, Spain)
Outline of the presentation

• GOODFOOD-Demonstration project
  – Fresh fish logistic chain
  – RFID system
  – Lab tests
  – Field Test

• Software “Fish Shelf Life Prediction Software FSLP”
  – Objectives
  – Results
  – Conclusions
  – Future work
GOODFOOD project

“FOOD SAFETY AND QUALITY WITH MICROSYSTEMS” (FP6-IT-1-508774-IP)
2004-2007

Objective:
Developing the new generation of analytical methods based on Micro and Nanotechnology (MST and M&NT) solutions for the safety and quality assurance along the food chain in the agrofood industry.

bringing the lab to the foodstuff...

...from the land to the market
GOODFOOD project. Food targets

- Milk and Dairy Products
- Fruits, juices and wine
- Fish

WP1: Antibiotics
WP2: Pesticides
WP3: Mycotoxins
WP4: Pathogens
WP5: Quality & Freshness
WP6: Logistics & Storage
WP7: Ambient Intelligence, Integration, Interconnection

Safety
Quality
GOODFOOD project

“FOOD SAFETY AND QUALITY WITH MICROSYSTEMS” (FP6-IT-1-508774-IP)

Objective (WP6): Development of a flexible tag for food monitoring during the logistic chain, integrating:

- physical sensors (Tª, rH and light)
- chemical sensors
- RFID communication capabilities
Demonstration project OBJECTIVE

“Monitoring for the chilled/frozen fish logistic chain based on Flexible Tag Microlab (FTM) system”

Implementation of an online $T^a$ and $rH$ monitoring system for the fresh fish logistic chain (based on the RFID tag developed)

- To enable a future generation of producers and logistic groups to trace fish at any time.
- To protect consumers from the consumption of unsafe fish.
Partners

RTD partners:
- **TEKNIKER** (coordinator): Micro and nanotechnologies
- **AZTI-Tecnalia**: Food research
- **University of Barcelona**: Electronics and communication

Industrial partners:
- **DECOEXSA**: One of the main European centres of perishables handling
- **Microelectronica MASER**: PYME. Electronic system production company
RFID tags: Radio Frequency Identification

Product identification technology based on radio waves → *Replacement for current bar codes* (expected in 10-15 years)

Main application: product tracking → in real time and without human interface
RFID system

The system has 2 parts:

1. **RFID tag: memory chip + antenna**
   - Memory → stores a unique and individual code and the data
   - Antenna → able to transmit the code and data to a reader
   - Attached on the product to be tracked

2. **Reader**
   - Wireless reading device
   - Reading distance: several cm – 10 m
   - Can also write info on the RFID tag
RFID tags: how do they work?

The *RFID Tag* receives a RF activation signal from the *reader* and answers sending the information loaded in the memory.

The *reader* processes the information and transmits it to a PC or PDA. And can also write information we send from a PC on the tag.
Challenge in RFID tags

**SENSORS integration → SMART RFID tags**
include **SENSORS** + memory chip + antenna

These sensors log data that can be stored in the memory

Sensors integrated for the Demo tag:
- Temperature
- rH
To test the smart labels with RFID, we selected the hake chain coming from South Africa to Europe:
The chain starts with the fish capture in South Africa and transport to the processing factory in refrigerated trucks…
Fresh fish logistic chain: details

On the processing factory the fish is gutted, sized and packed in polystyrene boxes.

A refrigerated truck transports the fish boxes from the processing factory to the origin airport in South Africa in a 12 hour journey…
Fresh fish logistic chain: details

The flight to the destination airport in Europe takes about 12 hours.

The destination airport can be Frankfurt (Germany) or Vitoria (Spain):

1. Frankfurt: fish is transported in refrigerated trucks to Vitoria, where the logistic company in Europe (Decoexsa) is located.
2. Vitoria: in the logistic company (Decoexsa) the fish boxes are re-organised according to their destination and re-expedited to the wholesalers.

Finally another refrigerated truck transports the fish boxes to the retailers.
**Current product identification in this chain**

**Identification of fish boxes with adhesive labels**

<table>
<thead>
<tr>
<th>Country of origin/País de origen</th>
<th>Size/Calibre</th>
<th>Date code/Fecha de producción</th>
</tr>
</thead>
<tbody>
<tr>
<td>REPUBLIC OF SOUTH AFRICA</td>
<td>1000-2000g</td>
<td>(7217) 4 Aug 2007</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product/Producto</th>
<th>Catch area/country of origin</th>
<th>Identification of fish boxes with adhesive labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merluccius Capensis / Paradoxus</td>
<td>• Catch area/country of origin</td>
<td>• Catch area/country of origin</td>
</tr>
<tr>
<td></td>
<td>• Product specie</td>
<td>• Product specie</td>
</tr>
<tr>
<td></td>
<td>• Net weight</td>
<td>• Net weight</td>
</tr>
<tr>
<td></td>
<td>• Catch method and vessel</td>
<td>• Catch method and vessel</td>
</tr>
<tr>
<td></td>
<td>• Presentation (whole, gutted…)</td>
<td>• Presentation (whole, gutted…)</td>
</tr>
<tr>
<td></td>
<td>• Exporter</td>
<td>• Exporter</td>
</tr>
<tr>
<td></td>
<td>• Importer</td>
<td>• Importer</td>
</tr>
<tr>
<td></td>
<td>• Date of catch</td>
<td>• Date of catch</td>
</tr>
<tr>
<td></td>
<td>• Size</td>
<td>• Size</td>
</tr>
<tr>
<td></td>
<td>• Freshness category</td>
<td>• Freshness category</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Net weight/Peso neto</th>
<th>Catch method/Forma de obtencion</th>
<th>Presentacion/Presentacion</th>
<th>Company/Company</th>
<th>Establishment nº/ nº de Establecimiento</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.60 Kg</td>
<td>EXTRACTO ARRASTRE</td>
<td>Con Cabeza</td>
<td>IRVIN &amp; JOHNSON LTD</td>
<td>D3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eviscerado</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vessel/Barco</th>
<th>Imparato/Importador</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREST LILY</td>
<td>PESCAFRESCA</td>
</tr>
</tbody>
</table>
Current T monitoring system

Single-use Strip Chart Recorder
need to open box and package to read

Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Range</td>
<td>-20°F to +100°F (-29°C to +38°C)</td>
</tr>
<tr>
<td>Operating Accuracy</td>
<td>±2.0°F (±1.1°C) full range</td>
</tr>
<tr>
<td>Day Spans</td>
<td>10 Day (°F &amp; °C)</td>
</tr>
<tr>
<td></td>
<td>40 Day (°F &amp; °C)</td>
</tr>
<tr>
<td></td>
<td>75 Day (°F &amp; °C)</td>
</tr>
<tr>
<td>Chart Resolution</td>
<td>10 Day 2.50 inches per day</td>
</tr>
<tr>
<td></td>
<td>40 Day 0.73 inches per day</td>
</tr>
<tr>
<td></td>
<td>75 Day 0.73 inches per day</td>
</tr>
<tr>
<td>Power/Shelf Life</td>
<td>1.5 volt AA battery</td>
</tr>
<tr>
<td></td>
<td>One year from date of purchase</td>
</tr>
<tr>
<td>Calibration</td>
<td>NIST Traceable</td>
</tr>
<tr>
<td>Tamper-Proof Security</td>
<td>Pre-sealed at the factory</td>
</tr>
<tr>
<td>Seal</td>
<td></td>
</tr>
<tr>
<td>Notice of Shipment</td>
<td>Three-part water resistant notice attached to CR-1</td>
</tr>
<tr>
<td>Case Count</td>
<td>40 instruments</td>
</tr>
<tr>
<td>Enclosure</td>
<td>ABS Plastic</td>
</tr>
<tr>
<td>Weight/Dimensions</td>
<td>10.5 ounces (297.7 grams)</td>
</tr>
<tr>
<td></td>
<td>6.50&quot; L x 2.56&quot; H x 3.50&quot; W</td>
</tr>
<tr>
<td></td>
<td>(16.51 cm x 6.5 cm x 8.89 cm)</td>
</tr>
</tbody>
</table>
New reader/tag system tested

**SMART RFID tag:** memory chip + antenna + T & rH sensors

- Tag prototypes fabricated
  - Rigid inlay
  - Flexible inlay
- Commercial reader: Texas Instruments TRF7960EVM
Technical features of the Tags tested

- RFID technology in the 13.56 MHz band was chosen
- Compatible with the ISO 15693 RFID communication standard
- Size of the prototype: 78 mm x 54 mm
- Semi-active tag
  - Passive reading
  - Active sensor read-out
  - Battery powered sensing part (thin film / mobile)
- Reading distance: 10 cm! (do not open boxes)
- Temperature and relative humidity sensors:
  - T accuracy: ±0.4° @ 0-40°C and ±1.5° @ -40-90°C
  - rH accuracy: 2% @ 10-90%
- Data acquisition based on
  - Alarm
  - Time
Software developed

- Read/Write on the tag
- Program the tag
- Control of tag status
- Access to traceability info
- Plot the logged data

The Smart Tag can be written, activated and read-out by means of the reader connected to a laptop running this specifically developed software.
Laboratory tests. Validation of RFID tag

- Climate chamber controlled conditions to test:
  - Temperature
  - Humidity logging
  for both the rigid and the flexible tag

Results were within specifications
Real-life implementation: 2 scenarios

1. Frankfurt → Vitoria: by road
2. South Africa → Vitoria: by airplane
Field tests

Smart tag protected from the fish distribution chain environment (water, salt, ice) using IP65 boxes.

The tags were placed inside a polystyrene box with the fish and cooling gels.
Field tests

The boxes containing the tags were sealed and packed with the rest of the boxes…
Field tests

... and were transported to the truck
Field tests

- Frankfurt → Vitoria in a refrigerated truck:
  Traceability data and $T^a$ and rH, were monitored online in a 35h journey
  Frequency of measurements: 2 minutes
RESULTS: Field tests

- Measured by 2 rigid and 1 flexible tags → $T^a$ was kept below 5°C along the complete journey

- Correlation of $T$ and $rH$ peaks with events along the truck transport

![Graph showing temperature and humidity over time with events marked]

- Departure from Frankfurt
- Stop open doors
- Arrival to Vitoria
- France: partial unload
- Fish boxes were loaded into the truck

Tag activation

$T(C)$ rigid tag1, $rH(\%)$ rigid tag1
$T(C)$ rigid tag2, $rH(\%)$ rigid tag2
$T(C)$ flex tag, $rH(\%)$ flex tag
RESULTS: Field tests

- South Africa → Vitoria (Spain): by airplane
- Measured by 2 rigid tags
- Correlation of T and rH peaks with events along the airplane transport
Conclusions

• **RFID smart tag system** developed has been demonstrated and validated along an international fresh fish logistic chain.

• **Integrates product traceability info and cold chain monitoring data**

• Traceability and cold chain data are stored in the Smart Tag memory and can be recalled at different logistic stages **without opening the polystyrene boxes** where the fish are packaged

• Can be **designed and programmed in multiple ways according to specific needs**
Future work

• Commercial credit card-like packaging of the tag or integration of the tag in the polystyrene boxes will be explored.

• Assess the scaling up from prototype → towards commercial smart tag
Thank you!

People involved in this project:

- Estefanía Abad (Tekniker)
- Aritz Juarros (Tekniker)
- Igor Goenaga (Tekniker)
- Jose M. Gómez (UB)
- Santiago Marco (UB)
- Francisco Palacio (UB)
- Cristian Vilar (UB)
- José María Navajas (Decoexsa)
- Jesús M. Iriondo (Maser)
- Maider Nuin (Azti)
- Alberto González de Zárate (Azti)

GoodFood project for the financial support
SOFTWARE “FISH SHELF LIFE PREDICTION SOFTWARE FSLP”
(AZTI-Tecnalia, Food Research Division, Spain and Institute of Food Research, Computational Microbiology Group, UK).
Objectives:

- To determine the shelf life of farmed fresh turbot at different storage temperatures. To explore the correlation of microbiological, sensory and time temperature integrators (TTI) data.

- To study the efficiency of several time temperature integrator (TTI) devices to predict the shelf life of farmed fresh fish.

- Develop a user-friendly software able to predict the shelf life of farmed fresh fish according to the microbial growth but also to the sensory evaluation.

Software “Fish Shelf Life Prediction Software FSLP” (AZTI-Tecnalia- Spain and Institute of Food Research, UK).
**Definition of time-temperature indicators TTI:**

- A simple, inexpensive device that shows an easily measurable, time-temperature dependent change that reflects the full or partial temperature history and quality status of the food product to which it is attached to. (Taoukis and Labuza, 1989)

Monitor Mark (3M)  
Check Point® (Vitsab)

Fresh Check® (LLT)

- **Response of TTIs:** Colorimeter (Minolta CR-200)
Software “Fish Shelf Life Prediction Software FSLP”

RESULTS

• Predict in fresh fish products the effect of storage conditions on microbial responses:

  ➢ growth of spoilage bacteria (log_{10} cfu/g)
  ➢ (hours) shelf-life in turbot.

• Sensory acceptability: rejection time (hours)

• Response of two commercial time-temperature integrators (hours): Monitor Mark ® and Fresh Check®
Software “Fish Shelf Life Prediction Software FSLP”

RESULTS

Fig 2: Output from “Fish Shelf Life Prediction Program (FSLP)” software showing the effect of a temperature profile on growth of total bacteria (red line) and the response of a trained sensory panel of turbot samples (brown line)
Software “Fish Shelf Life Prediction Software FSLP”

RESULTS

• Available free version of the software “Fish Shelf Life Prediction Program FSLP” in internet (industry, food inspection services, teaching, research and consumer organisations)

• http://www.azti.es/

http://www.azti.es/muestracontenido.asp?idcontenido=980&content=15&nodo1=30&nodo2=0 (VERSIÓN EN CASTELLANO)

http://www.azti.es/muestracontenido.asp?idcontenido=981&content=15&nodo1=30&nodo2=0 (VERSIÓN EN INGLÉS)
Modelling shelf life and quality on real fish products is difficult but possible.

To predict shelf life it is important to have information about raw materials, to have the time-temperature profiles of the product.

We have developed a software able to predict the shelf life of farmed fish (turbot) products taken into account microbial and sensory parameters.

Prediction softwares: to have important information about seafood product quality and safety. Traceability tools.
Software “Fish Shelf Life Prediction Software FSLP”

Plans for the future

• Validate the software with more fish species and products (fresh and lightly preserved seafood)

• Software: combination of shelf-life models and traceability tools (e.g. data logger or radio frequency identification tags RFID)
THANK YOU!!

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Yan Le Marc

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