

Recent research and progress in measuring and improving the performance of the cold chain

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1st IIR International
Cold Chain and Sustainability
Conference





Refrigeration and food worldwide ...

60% of the food we eat in developed countries needs cold application.

ie 350 MT of food per year are actually refrigerated, whereas 1 500 Mt could be refrigerated to good effect

Approx 8 % of the world electric consumption

(16 424 / 1 300 TWh)

⇒ **Estimated global effect : 2.5 % of the world GHG emissions in eq CO2**

(49 / 1.3 G Teq CO2)

An increasing impact in the forthcoming decades

Refrigeration and food worldwide ...

Research, progress and performance of the cold chain :

1. Improve trust and reliability in the different links of the food cold chain,
2. Develop new equipment and/or processes adapted to the different links of the cold chain (or at least, improve the current performances),
3. Reduce the environmental impact of refrigeration systems.

Sustainability of the cold chain is at this price ...

Refrigeration and food worldwide ...

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Monitor and observe the temperature along the cold chain to demonstrate its performance (and/or weaknesses ...) and warn the user, the consumer

An example of recent research

The results of a French survey on refrigerated industrial fresh or prepared every day food product sold in self-service counters of super and hyper markets
(do not extend the results to other products and logistic circuits)

How to proceed to have a complete and reliable view on the refrigerated food cold chain, and how to exploit the results ?

► Protocol

Self contained temperature recorder inserted in the product itself



The instrumented package was unrecognizable from the other packages



► Protocol

The instrumented package is then sent in the logistical circuits and returned by the consumer himself



- ◀ Press releases
- ◀ Explanation booklet
- ◀ Reward of 25 €

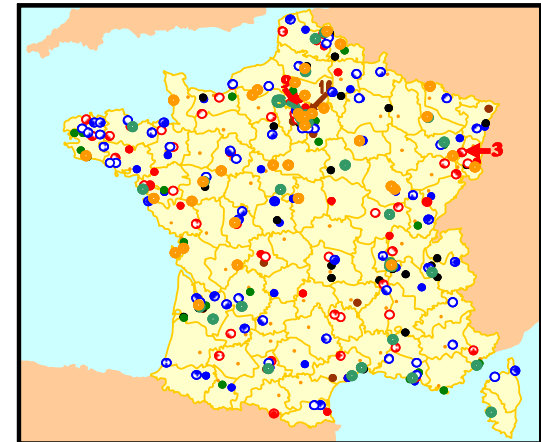
► Results

Available data

- 480 sensors sent, 314 exploitable return
- 3 887 recording days
- 2 350 steps of the cold chain observed
(included 307 display cabinets and 251 domestic refrigerators)

Representativity

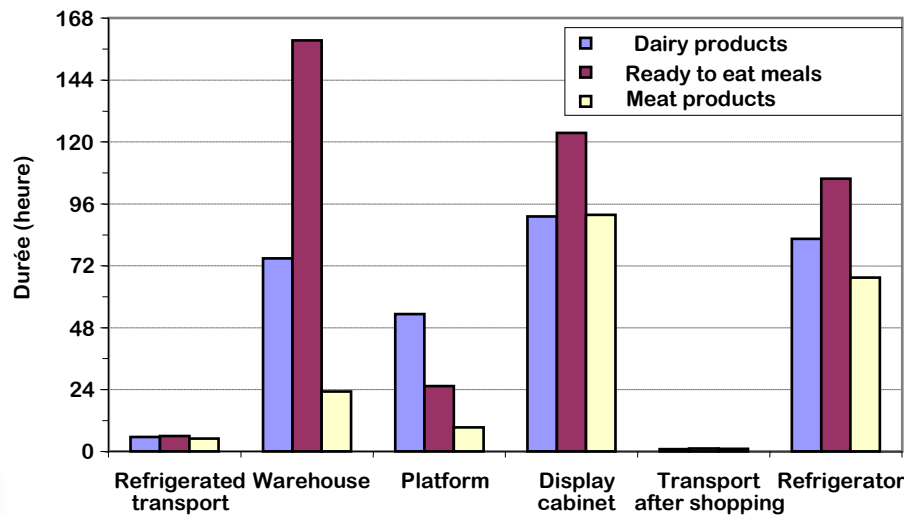
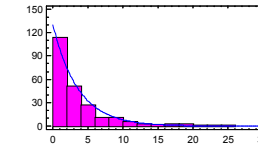
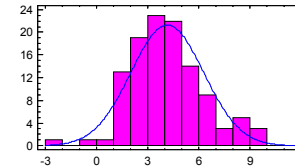
- These data only concern refrigerated industrial fresh or prepared every day food products sold in self service counters. It represents 60% of the agro-industrial foods sold in these channels, *ie* 10 % of the refrigerated food we consume.
- It is not extendable to the cold chain of other products (for instance fish products) or to home-made products distributed on open markets.



▶ Quantitative results

Some precious statistics (mean, variance and distribution law) in the different links of the cold chain

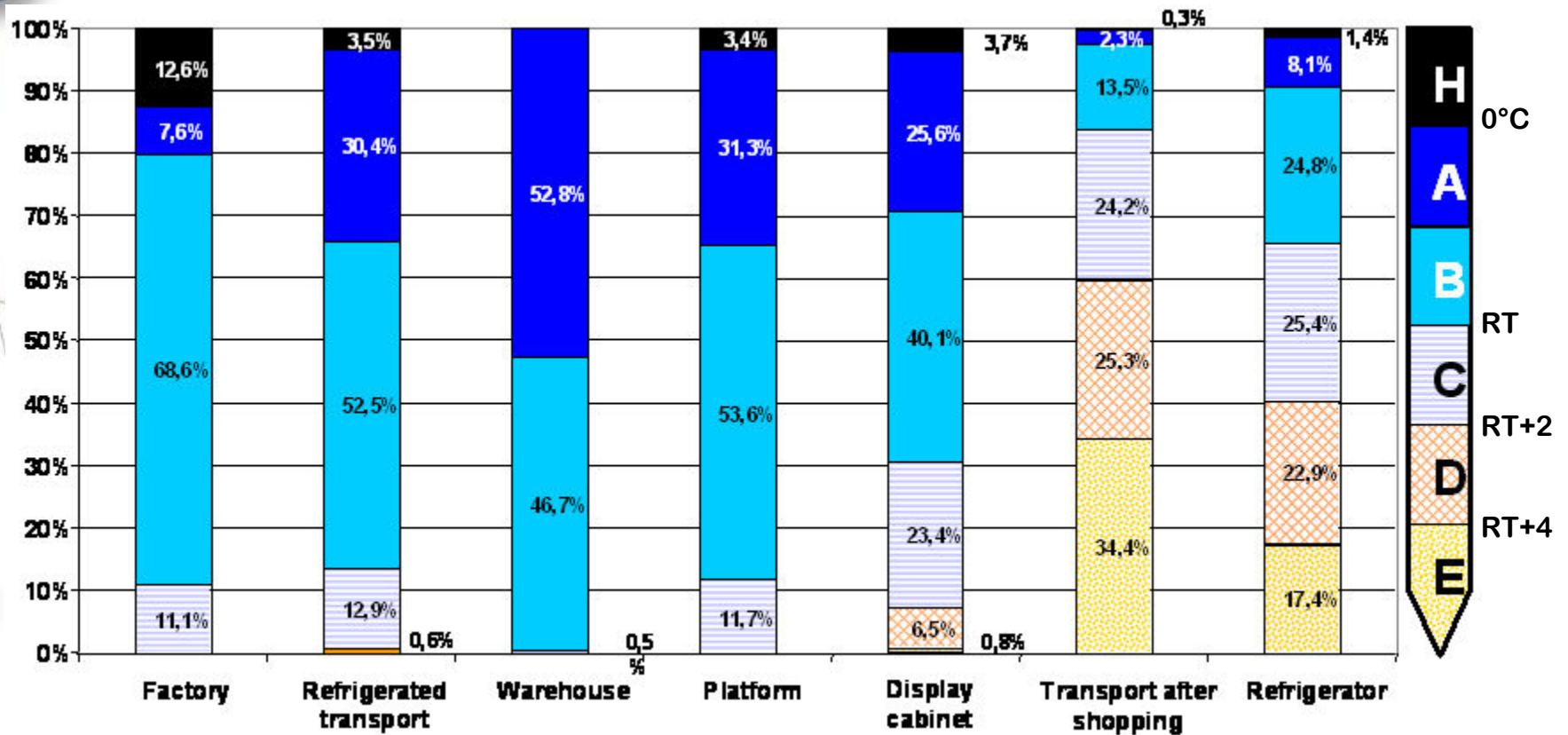
- On temperature
- On residence time
- On the organization of the distribution circuits



Number intermediates	% observed
0 (direct delivery)	9.3
1	34.9
2	46.7
3	8.6
4	0.5
Total	100

► What to do with these statistics ?

Verify the regulation's respect



A good professionalism of the upstream part of the cold chain

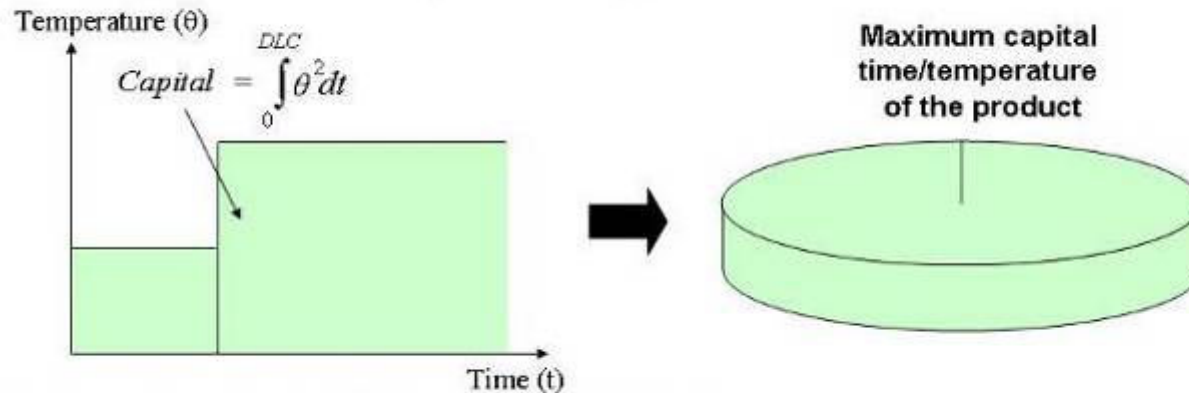
Weakness of the links managed by the consumer

▶ What to do with these statistics ?

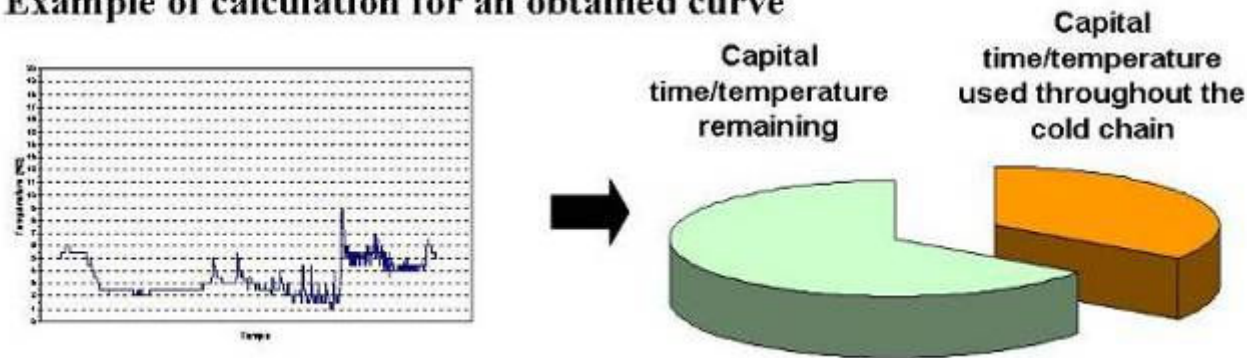
Evaluate the food safety

Based on $\int \theta^2 dt$ inspired from basic predictive microbiology

▶ Example of validation protocol of product shelf life



▶ Example of calculation for an obtained curve



▶ What to do with these statistics ?

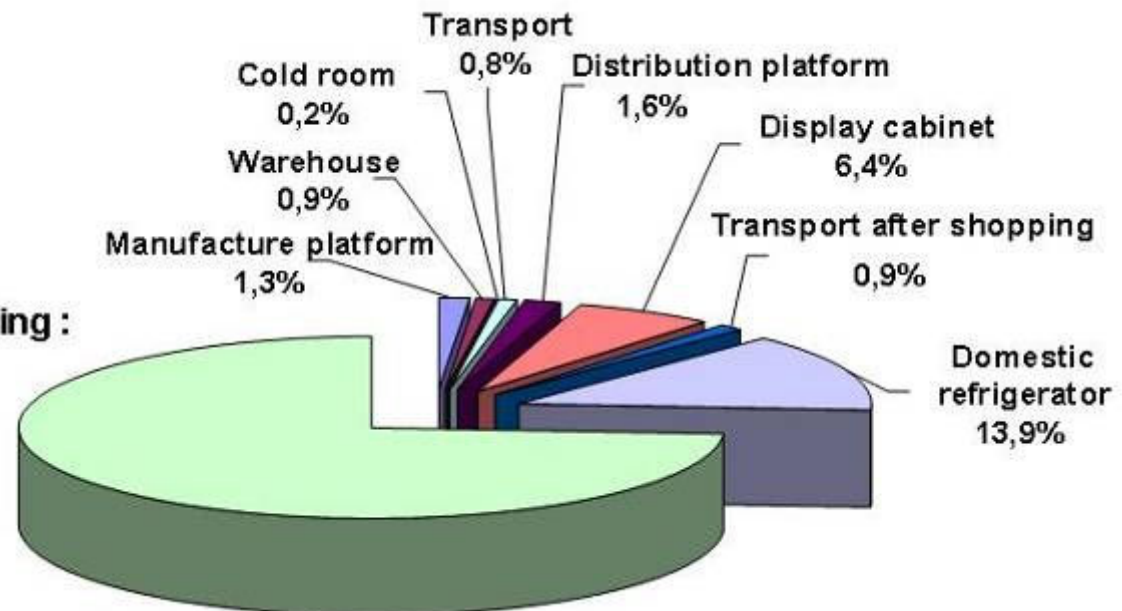
Detect the main weaknesses of the cold chain and propose solution to solve the problem

A typical example on a meat product

Capital time/temperature remaining :

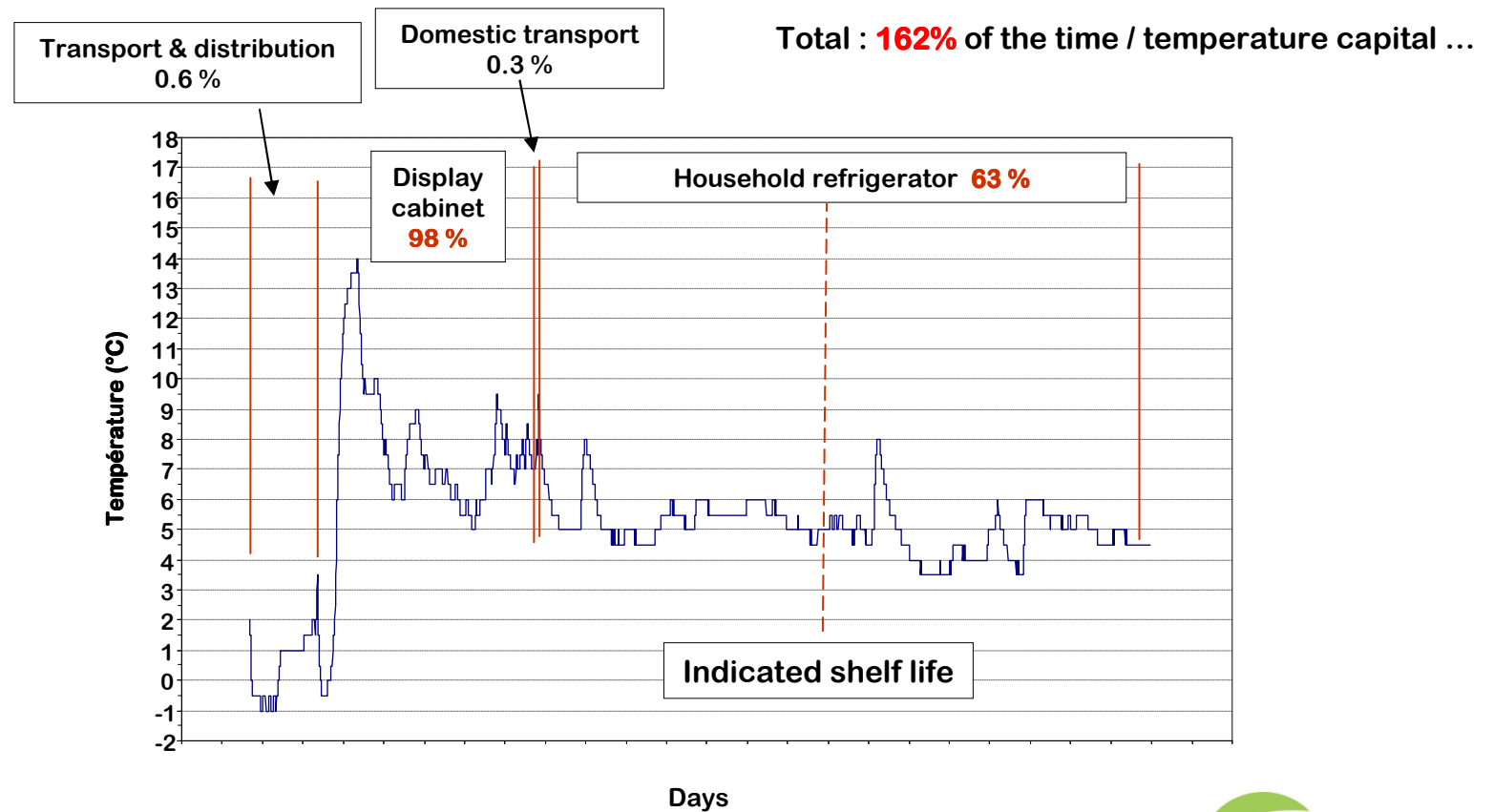
Average : 74%

(min: 0 % ; max: 96 %)



What to do with these statistics ?

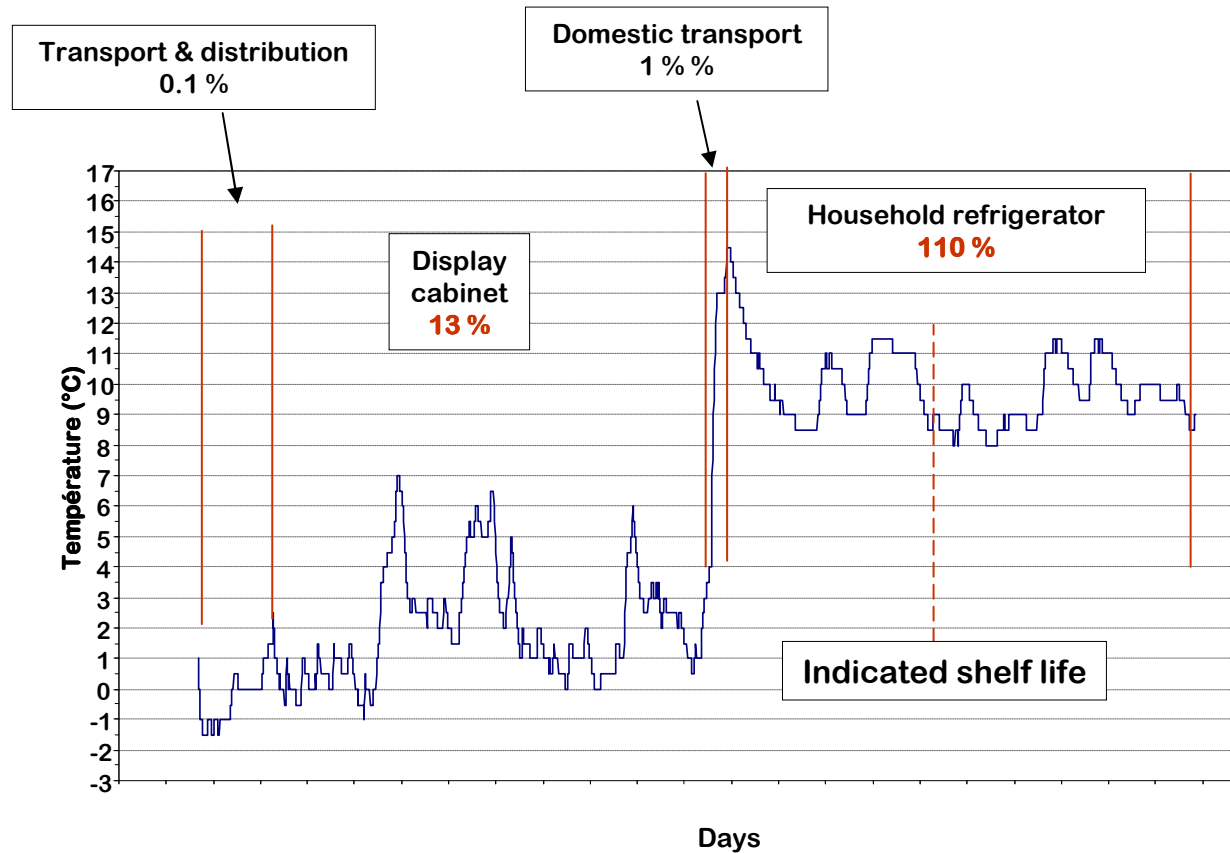
Some excess sometimes attributable to the industrial part of the cold chain ...



What to do with these statistics ?

.. and more often to the consumer's behavior ...

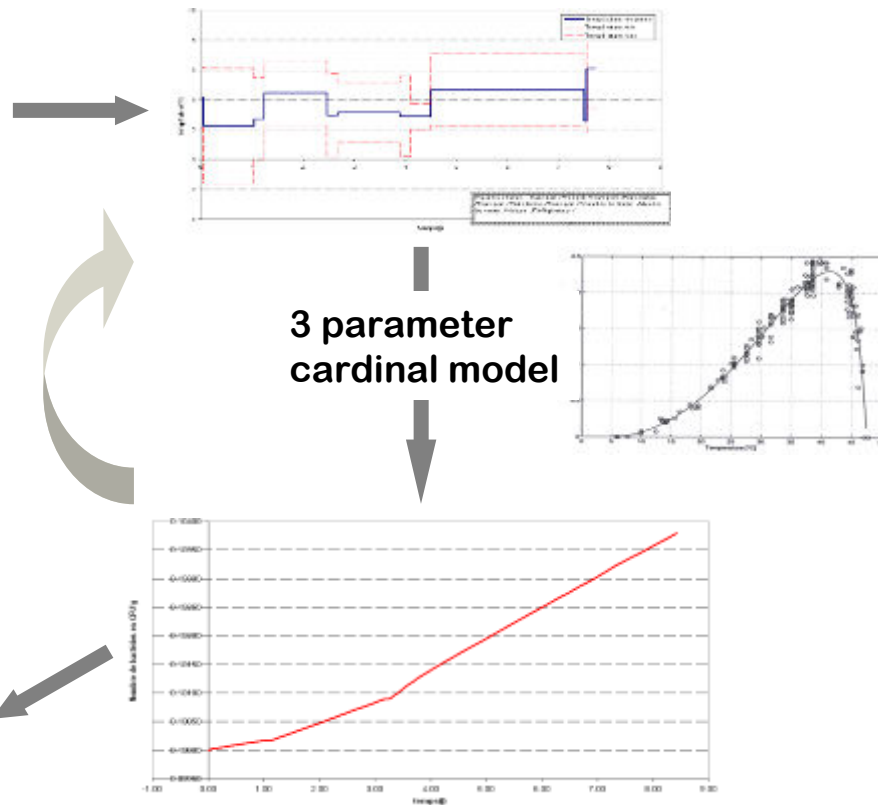
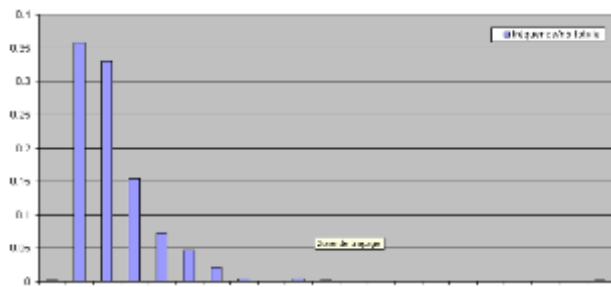
Total : **123%** of the time / temperature capital ...



▶ What to do with these statistics ?

Assist the industrials to enhance and refine the definition of shelf life's protocols

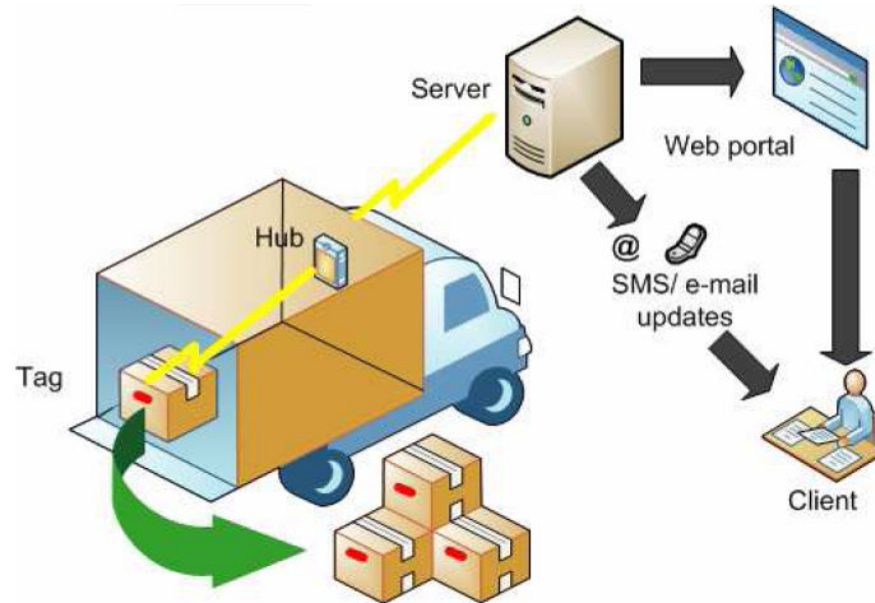
- Simulate a probable cold chain by random sampling in these distribution function (Monte Carlo simulation).
- Translate the thermal history of the food in microbial load by integration step by step (predictive microbiology)
- Repeat the procedure to have an estimation of the distribution function of the product temperature and the microbial load in food.



Siliker award for L. Li and E. Derens work

► Users and consumers : how to enhance trust ?

=> Monitoring to demonstrate the performances



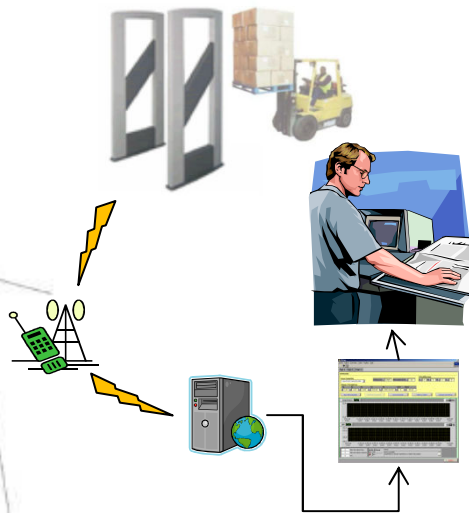
Taking advantage of RFID and telecommunication developments

Number of ongoing research & development projects on the topic

Cf 4th informatory note of the IIR

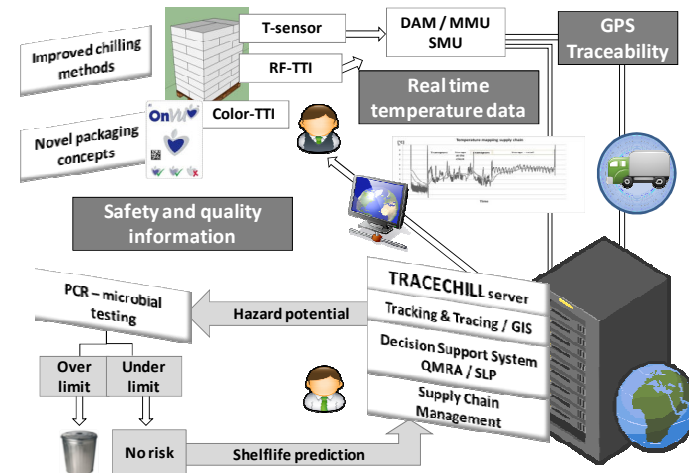
▶ Monitoring the cold chain

⇒ Enhance (and demonstrate ?) the performance of the industrial part of the cold chain



ID-Tag NRA-French project
 ⇒ Microbial integration on cardinal models; possible selection of a specific strain (spoilage and pathogenic)

Real time calculation of the remaining shelf life capital
 ⇒ An opening to the variable shelf life notion (depending on the past thermal history of the food).



Chill-On EU project
 ⇒ Microbial integration (presented during the conference)

▶ Monitoring the cold chain

**Continuous monitoring and from production to delivery:
it is possible today.**

Some questions are now open ...

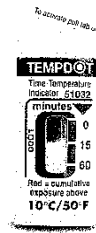
- ▶ **Before, the rules were easy to interpret (yes / no). This regulation will be maintained : at the moment, public bodies cannot accept to modify an existing, clear and efficient rule.**
- ▶ **Tomorrow it could be more difficult to interpret: a product may be considered spoiled before its use-by date, or be deemed edible after this date ...
What to do with this information ? Who will endorse this responsibility ?**
- ▶ **Who will cover the costs of the implementation of such technologies ?**

Nevertheless, these elegant, efficient and exciting techniques and technologies will probably have a bright future ... for the industrial part of the cold chain (only).

▶ Monitoring the cold chain

Continuous control from delivery to consumption :
it is also possible today.

=> By informing and educating the consumer, and by warning him on the packaging ...



Temperature Indicators



Time Temperature Integrators

The reliability of these tags remain to be proved and accepted by users. Research (physico-chemical reaction, microbiological evolution, ...) and standardization has to continue ...

The problem remains to be solved

Cf 3rd Informatory note of the IIR



Towards a sustainable cold chain ...

1. Improve trust and reliability in the different links of the food cold chain,
2. **Develop new equipment and/or processes adapted to the different links of the cold chain (or at least, improve the current performances), in order to respect food quality and food safety constraints**
3. **And at the same time, reduce the environmental impact of refrigeration systems and processes.**



Towards a sustainable cold chain ...

In few words : Equipments and processes

- **Existing equipments will continue to exist for a long time**
(warehouses, refrigerated transport, display cabinets and household appliances...)
- **Incremental progress in the development of equipments**
CFD optimisation of the performances of equipments
- **Work on “new” chilling processes**
(perfusion chilling, deep chilling, mist chilling, immersion chilling, impingement chilling, electro freezing ...)
Coupling the process and the food quality objective (both on organoleptic and on microbial point of view)

Highlighted by some exciting presentations during the present conference

Towards a sustainable cold chain ...

In few words : Refrigeration technologies

- Present equipments and thermodynamics cycles (vapour compression with liquid / vapour phase change) will continue to exist for decades (no reasonable rupture at 10-20 years horizon)
- Active work
 - In the field of the control of refrigeration systems (direct coupling between a required performance, an energy consumption and a *product's quality* objective)
 - On the refrigerant charge reduction (mini channels, efficient secondary refrigerants) and on the mitigation of GHG emission
 - On the use of natural working fluids
 - On the magnetic refrigeration

▶ IIR contribution : Working parties

- Cold chain optimisation (D. Tanner)
- Data and Models for Refrigeration and Freezing Foods (B. Nicolai)
- Energy Labelling in the Cold Chain (G. Cortella)
- Refrigerant charge reduction (H. Macchi)
- Mitigation of Emissions of Greenhouse Gases in Refrigeration (P. Lund)
- Ice slurries applications (L. Fournaison)
- Magnetic refrigeration (P. Egolf)



☞ Join IIR Working parties.

☞ Participate to the IJR special issues on these topics

▶ Conclusion

- Refrigeration demand will continue to grow steadily in the future
- Development has to take into account consumer's and society's demands (trust and reliability), as well as performance, energy consumption and environmental print
- Toward a sustainable cold chain : it is possible

**Have a nice conference
... and thanks to the organisers.**

