A consequent cool chain – backbone for minimally processed food

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EFFoST Symposium “Innovations in food processing and product development”
26.03.2012

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- Temperature monitoring in food chains: Face the Facts
- Temperature control of food products - Visions
- Linking temperature data with shelf life models
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Factors influencing food quality and safety of minimally processed food

Minimally processed food

Product internal factors

- water activity
- nutrient content
- pH-value

Process factors

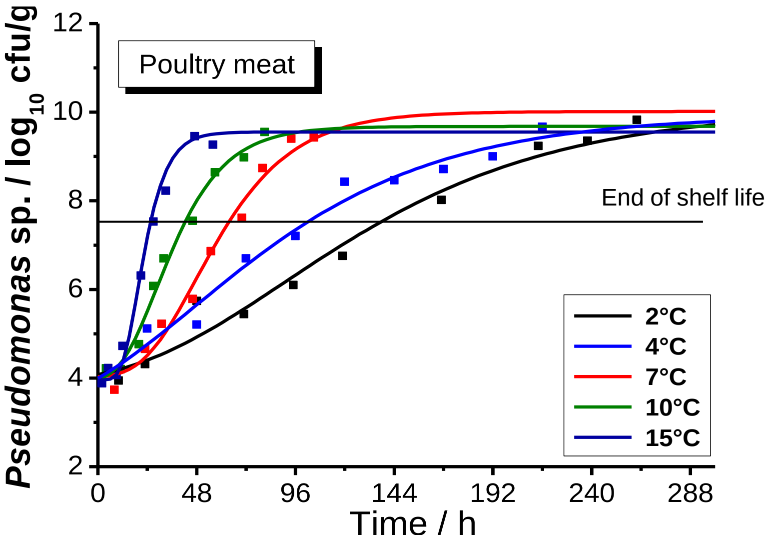
- process hygiene
- physical treatment (ozone)

Environmental factors

- humidity
- gas atmosphere
- temperature

Influence of temperature on food quality and shelf life

Growth of *Pseudomonas spp.* on fresh poultry as function of temperture

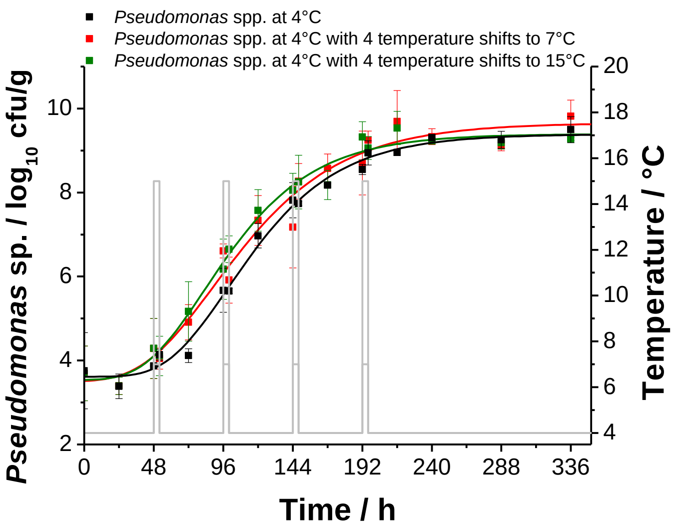


Bruckner, 2010

	Shelf life* (shelf life reduction)	
Tempera-ture	**pork**	**poultry**
2°C	7 days	5 days
4°C	5 days (-28 %)	4 days (-20%)
7°C	4 days (-43 %)	3 days (-40 %)
10°C	3 days (-57 %)	2 days (-60 %)

* Evaluated by count of *Pseudomonas sp.*: End of shelf life: 7,5 log_{10} cfu/g

Influence of temperature on food quality and shelf life



Growth of *Pseudomonas* sp. on poultry at 4°C (constant) and at 4°C with 4 temperature shifts for 4 hours to 7°C resp. 15°C

	Shelf life* (shelf life reduction)	
temperature	**pork**	**poultry**
4°C constant	8 days	6 days
3 shifts for 4 hours from 4°C to 7°C	6 days (-25 %)	5 days (-17 %)
3 shifts for 4 hours from 4°C to 15°C	5 days (-37 %)	4 days (-33 %)

➡ A consequent cold chain is important to obtain high quality and safe products

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Temperature monitoring in food chains








Slaughtering and processing

evisceration | processing packaging | cooling room (storage)

Trans-port (TS) → **Wholesaler** → **TS** → **Retailer** → ~~**TS**~~ → ~~**Consumer**~~

Data exchange

control of environmental temperature

Radom measurement product temperature
(internal quality inspection)

measurement product temperature
(incomming inspection)

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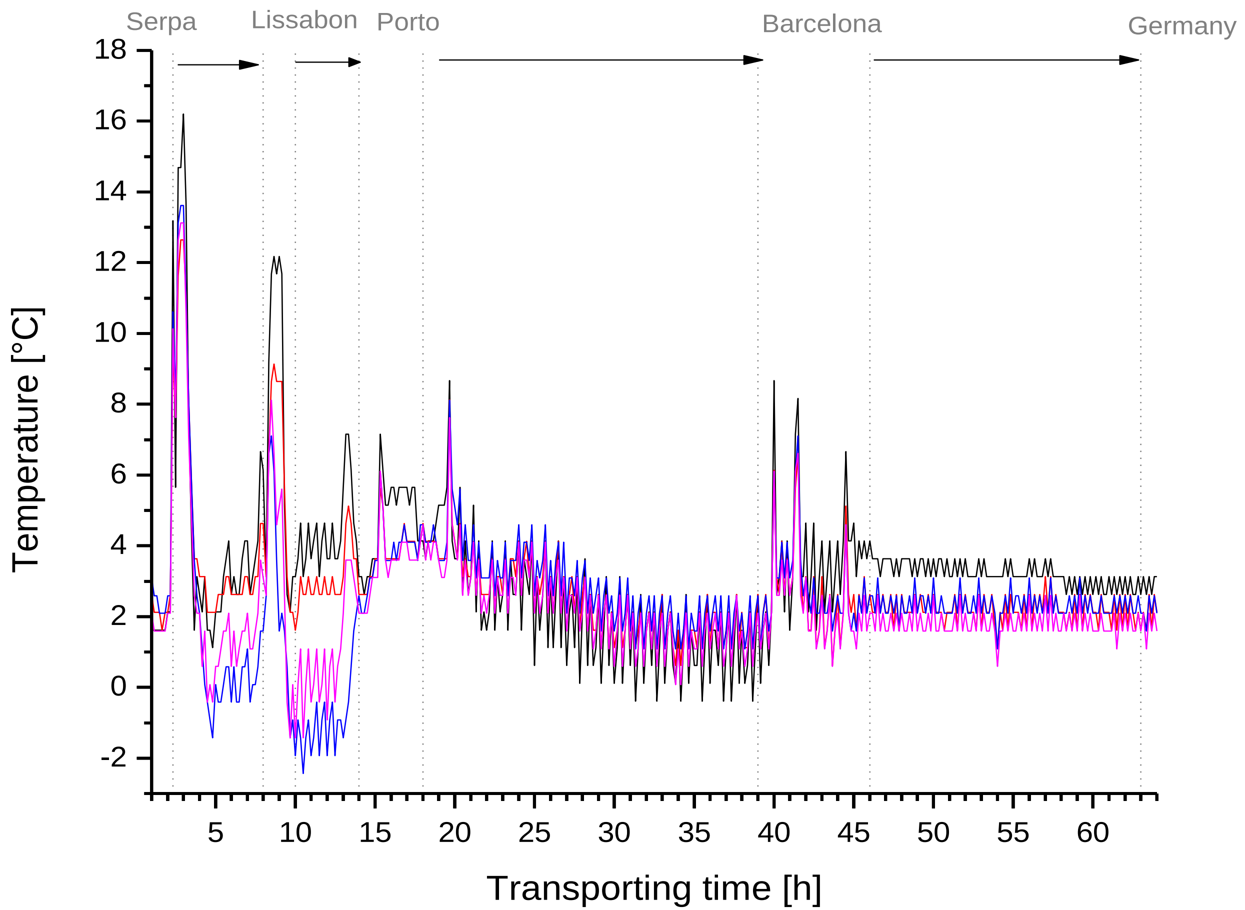
Temperature monitoring in food chains:„Face the Facts“

Typical weak points in cold chains:

- Transfer points within the supply chain, especially from one actor to another (e.g. waiting times at dispatch and loading points)
- Door opening times during transports
- Mixed-transports with high and low temperatures goods
- Inappropriate handlings and storages of the goods inside the retailer-stores
- Transport after the POS
- Storage in the private refrigerators

Temperature monitoring in food chains:„Face the Facts“

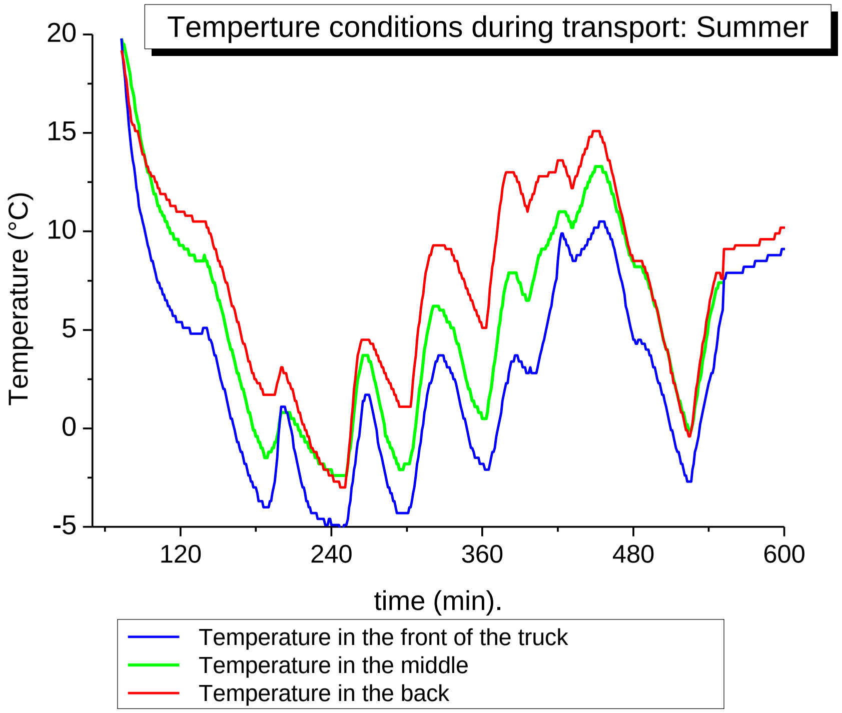
- Temperature profile at the outside of a pallet with pork meat during the transportation from Portugal to Germany

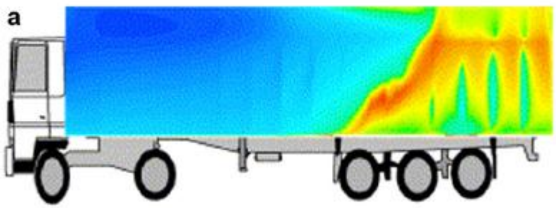


Mack, 2011

Temperature monitoring in food chains:„Face the Facts“

➢Temperature variations during transportation (trucks, container...) are often not detected





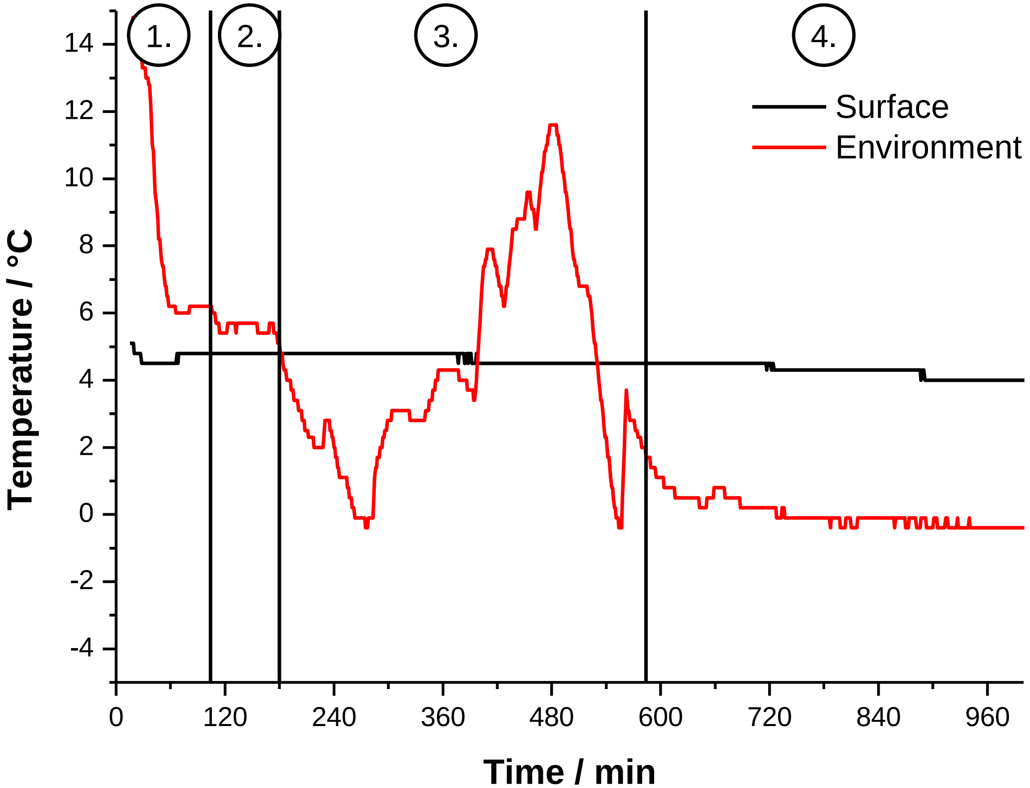
Temperature (°C) in the truck (summer):
Back: 7,8 +/- 2,2; mittle: 5,3 +/- 5,1; front: 2,4 +/- 4,9

Kreyenschmidt, 2007, Moureh & Flick 2004

Temperature monitoring in food chains:„Face the Facts“

- Measurement of the environmental temperature is not always sufficient since it can differ significantly from the product temperature

Temperature variations at one single cardboard box at the bottom of the palette



1: Area of consignment sale/ docking station

2: Transportation step

3: Transportation step: start of unloading phase

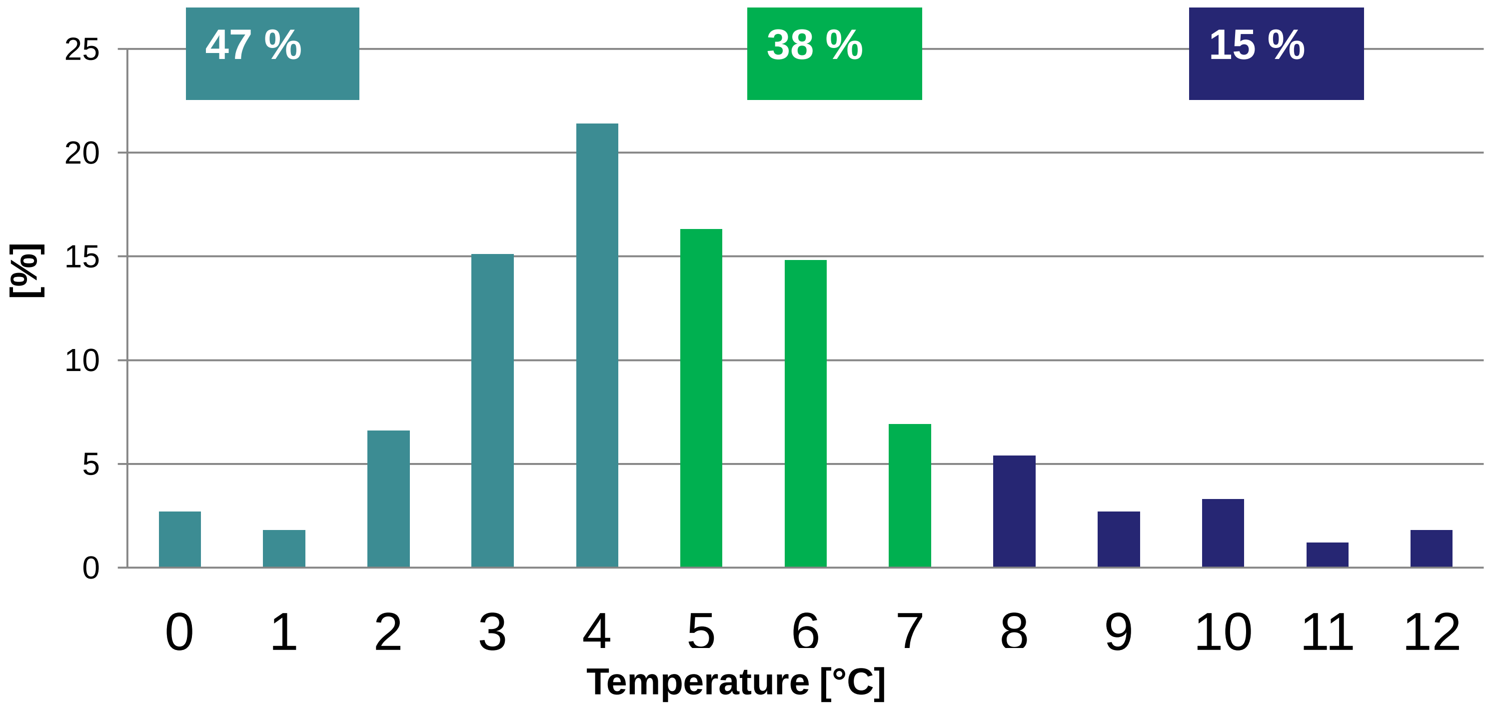
4: Wholesaler

Raab et al, 2008

„Face the Facts"

Temperature in private household refrigerators

- Interruption of the cold chain often take place after the Point of Sale
  For consumer interruption of the cold chain is mostly not detectable



Thomas, 2007

Temperature monitoring in food chains:„Face the Facts“

- Weak points are often undetected, e.g. at handover points
- Measured temperature-data are often not meaningful:

➡

- **The product quality and safety differ significantly because of different temperature conditions in the chain**
- **Several products are spoiled before the best-before date is reached**
- **best-before date is often not meaningful**

Temperature control of food products - visions

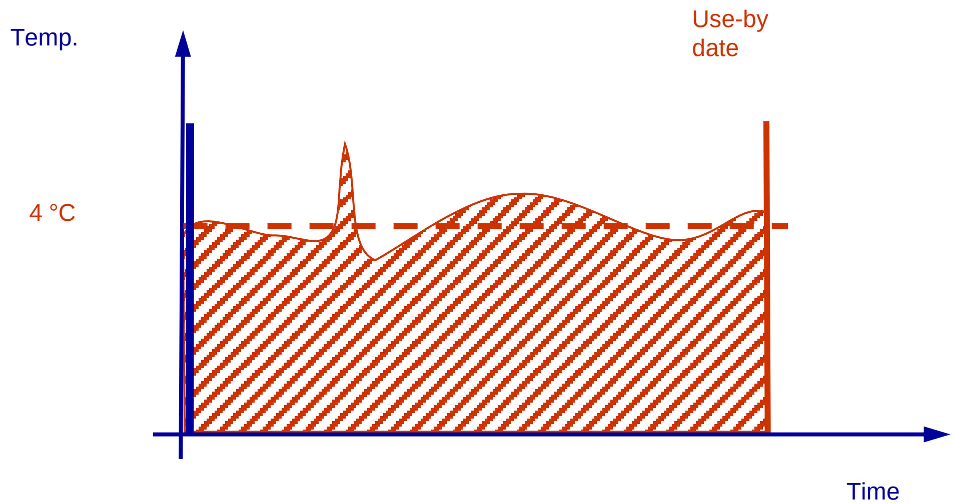
- **1. Continuous control of the product temperature during the chain**
- **2. Linking temperature data with product data**
  - Optimized information about the quality and safety of a product in each step
  - Improvement of the storage management (FE-FO instead of FIFO)
  - Reduction of food waste

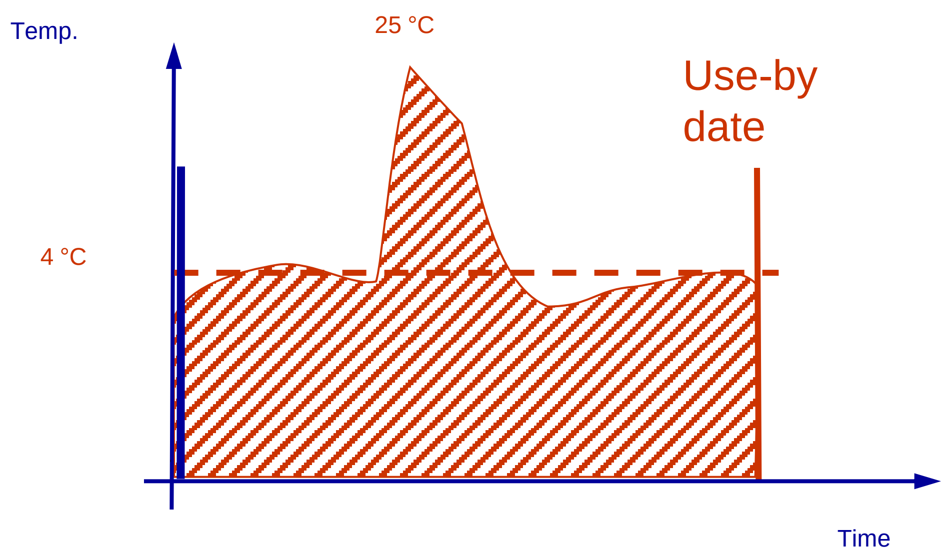
1. Continuous control of the product temperature during the chain

Time-Temperature Indicators: Sensors which show the temperature history of products by colour change

Principle: chemical, physical, enzymatic or microbiological reactions

Time- Temperature Indicator



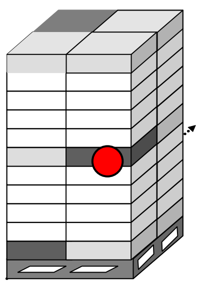


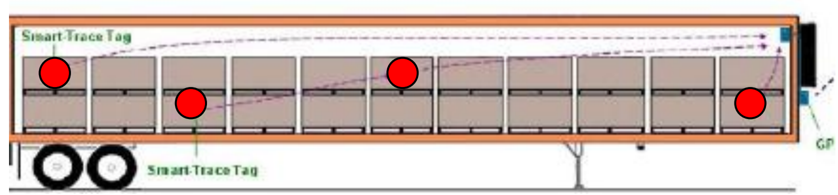
Fuchs, 2011

1. Continuous control of product temperature during the chain

- Implementation of innovative temperature monitoring devices,
  e.g. Smart Active Label or other RFID based temperature monitoring devices

- The kind of implementation depends on the prices of the monitoring systems, of the product prices, the packaging, chain structure, ….





- In combination with heat transfer models a prediction of product temperature as a function of time and ambient temperature is possible

1. Continuous control of product temperature conditions during the chain

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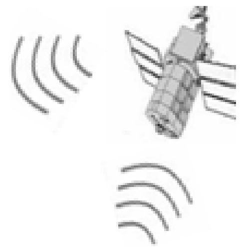
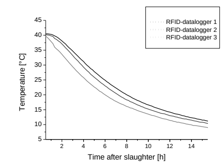
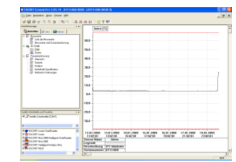
Supplier / Customer

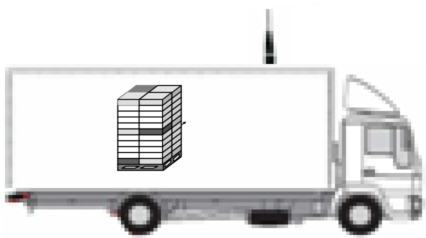


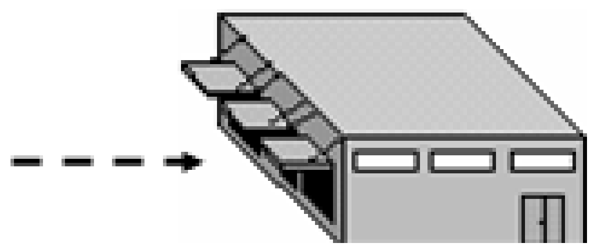


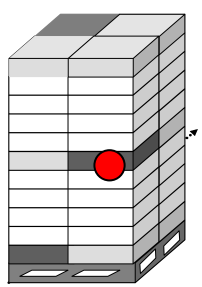


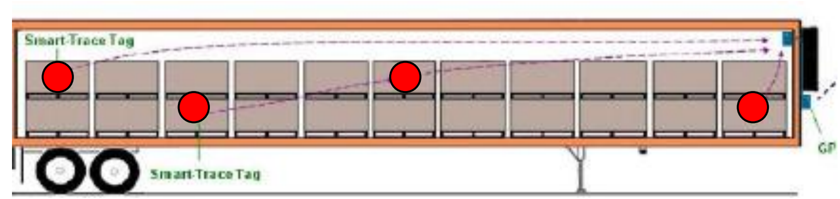
Server / heat transfer model

GPS / GSM / GPRS









2. Linking temperature data and product data

Options to link temperature data with:

- growth models and risk models of product specific pathogenic bacteria
    - **product safety**

- kinetic models of product specific spoilage organisms or other specific spoilage parameters (sensoric, chemical or physical parameters)
    - **product quality and shelf life information**

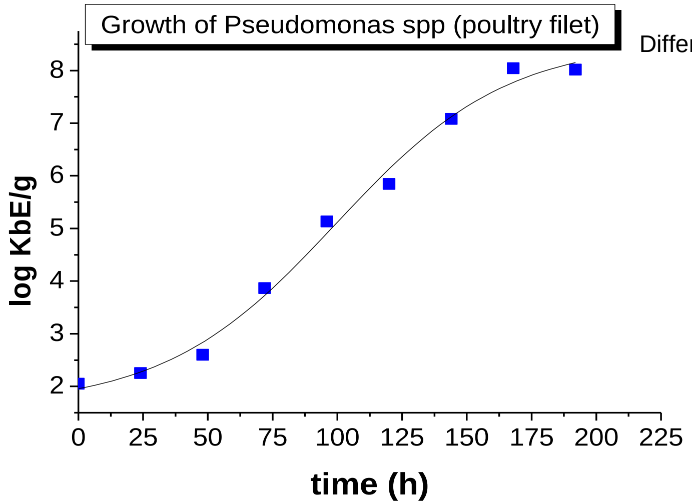
Model to predict the product quality and shelf life (primary model)

1. Definition of the quality parameter and quality function
   - Investigation of the development of the quality parameter

$$\frac{d[Y]}{dt} = k[Y]^m$$

Y = qualiy parameter,
k = raction rate constant,
t = time, m = reaction order
Q =quality

Development of the model to decribe the freshness loss as function of the time - for microbiological parameter e.g. Gompertzmodel



Differenz zwischen Anfangs- und Endkeimgehalt

$$N(t) = N_0 + a \cdot e^{-e^{-k(t-xc)}}$$

N(t) =Microbiological count at time t,
a = Difference between N_{max} and N_0,
k = relative growth rate at xc
t = time, xc = inflection, N_0 = initial count

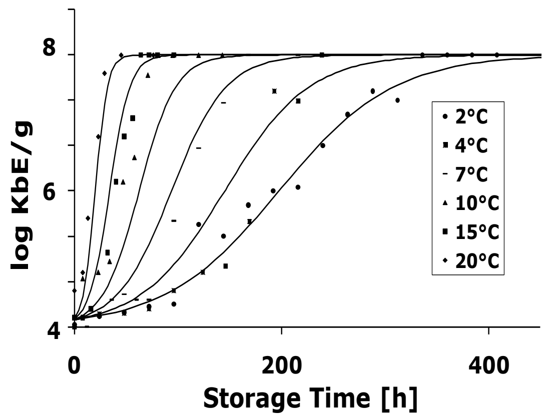
Model to predict the product quality and shelf life (secondary model)

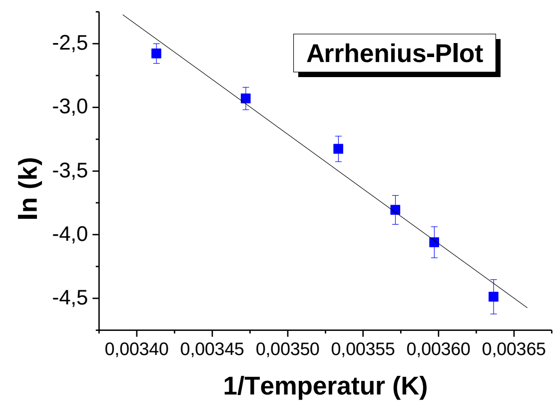
2. Development of a model to describe the freshness loss as function of temperature
   - Investigation of the freshnessparameter under different isothermal temperatures
   - Development of a model to decribe the freshness loss as function of temperuture
   e.g. Arrhenius modell

$$\ln(k) = \ln(k_0) - \frac{E_a}{R} \cdot \frac{1}{T}$$

k = reaction rate constant, ka = pre-exponential factor
Ea = activation energy, t = Temperature, R =gas constant

Growth of Pseudomonas under differnt temperature conditions

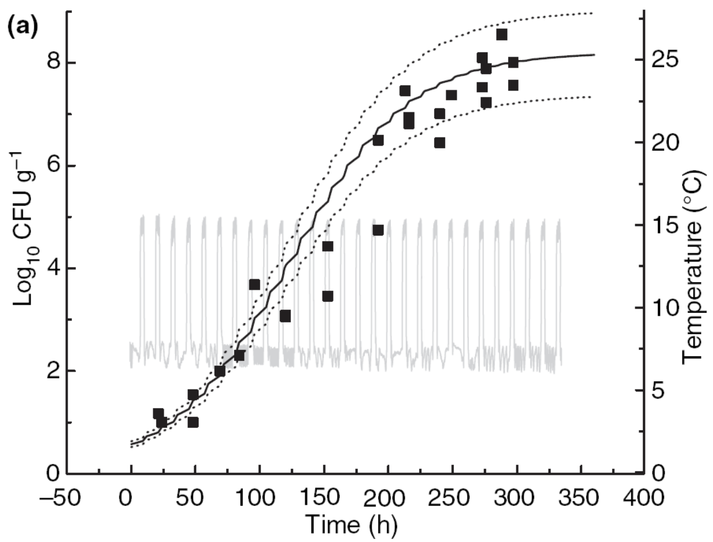




Model to predict the product quality and shelf life (tertiary model)

3. The quality function allows the prediction of the quality parameter as function of the temperature resp. as function of the time temperature history of the product

$$N_t = N_0 \cdot e^{[\mu \int_0^t e^{\frac{-E_A}{R \cdot T(t)}} \cdot dt)] \cdot t}$$



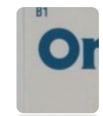
Kreyenschmidt et al, 2010

Practical implementation
Shelf life model combined temperature monitoring devices





Slaughtering and processing: evisceration | Processing | cooling room → **Trans-port (TS)** → **Wholesaler** → **TS** → **Retailer** → **TS** → **Consumer**

Measurement of the temperature data or color value of the TTI

↓ Data transfer

Microbiological shelf life model

↓

Calculation of the remaining shelf life in each step of the chain

Control point temperature data

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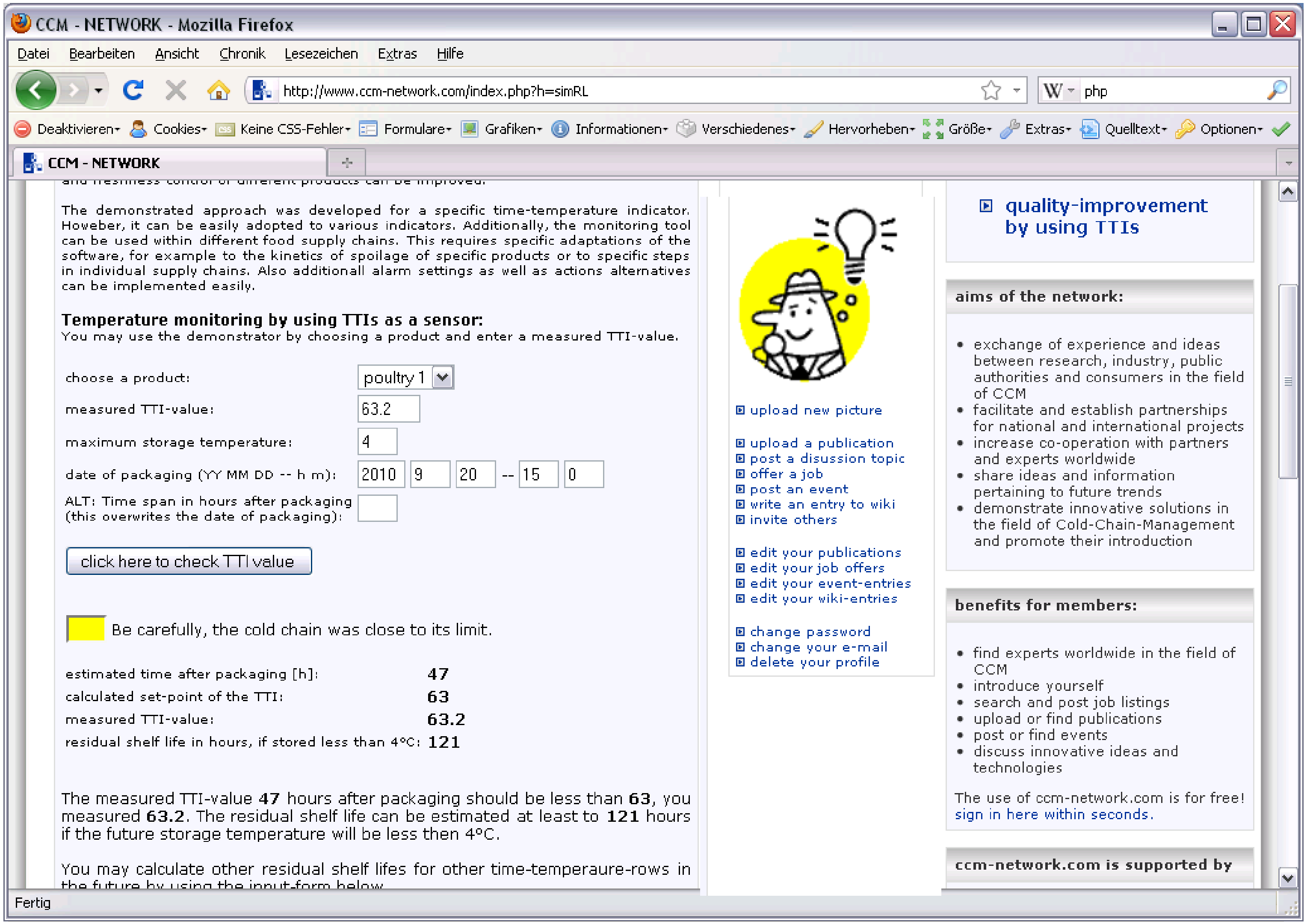
Software Tool to predict the reaming shelf life based on the temperature history



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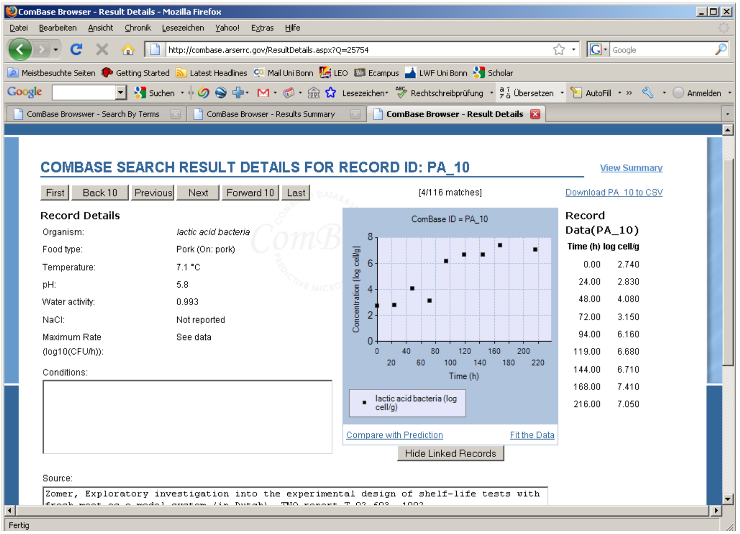
Further Software Tool to predict the quality and safety of food

ComBase-PMP
(http://www.combase.cc)

Seafood Spoilage and Safety Predictor (SSSP)
(http://sssp.dtuaqua.dk)

Sym'Previus Software
(www.symprevius.org)

Campden BRI
(http://www.campden.co.uk/news/mar09.pdf)



The implementation of shelf life models within food chains

A successful implementation of quality and safety models and stability data requires:

- precise measurement of the product temperature over the whole chain to get accurate predictions for food quality and safety parameters
  - Correct placement of the monitoring devices
  - Adequate number of loggers to reflect the temperature off all products
  - Consideration of packaging material

- Exchange of temperature data between the supplier and customer

- Intensive staff training:
  - Correct application of temperature monitoring systems,
  - Know-how about the product and the effect of temperature abuse on the product

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Summary

Vision:

- Continuous control of the product temperature from production to consumption
- Linking temperature data with product data
    - ***reduction of food waste and food born diseases (safety), improving quality***

Current limits:

- Several temperature monitoring systems have been developed in recent years, but guidelines about a successful implementation for specific chains and products are still missing (risk based monitoring: logger placement, measurement frequency, no of loggers..)

- Food chains are complex and heterogeneous, the exchange of temperature data over the entire supply chain is limited (matter of trust), communication is missing

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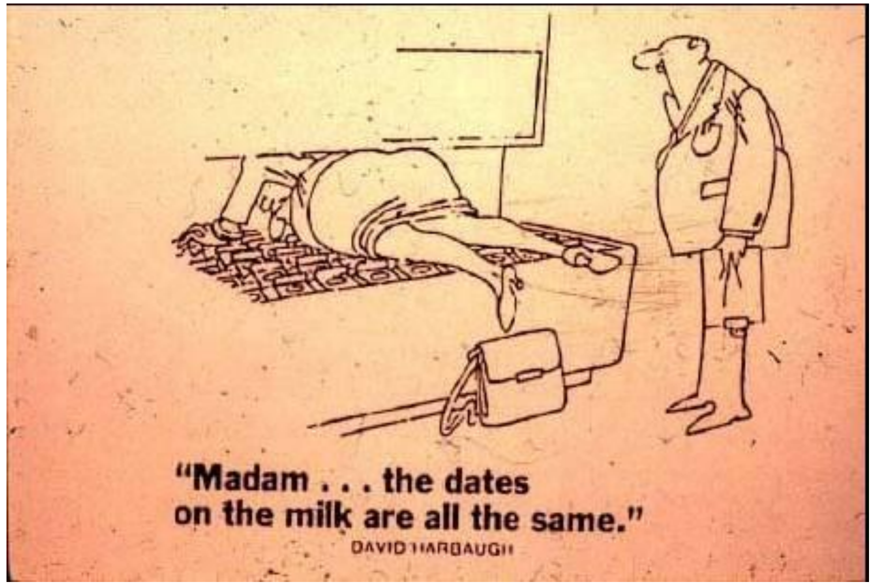
Temperature control of food products: vision and limits

Current limits:

- There is a missing awareness about the impact of temperature abuses on the quality and safety of food (e.g. drivers, warehouse personal)

- The consumer have to be integrated in the overall concept
  - solutions are limited (except TTIs); but retailers are not willing to implement TTIs

Thanks!!!



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Research Topics: shelf life models, temperature monitoring systems, intelligent packaging technologies

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- Minimal processing
  means that the product was processed in a manner that does not fundamentally alter the product.