



WEB2.0 based Software Solution to support a practical implementation of Time Temperature Indicators

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Verena Raab / University of Bonn

Outline of the presentation



- Motivation to develop a software to use TTIs in cold chains
- Short description of Time Temperature Indicators
- Development of a TTI kinetic model that also describes the spoilage of food and what is the basic algorithm for the software
- Field trial to validate the TTI kinetic model and the usability of Time Temperature Indicators within cold chains
- Presentation of an Internet based software to improve the cold chain management with the use of TTIs

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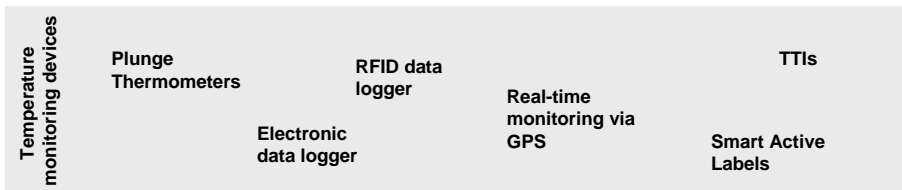
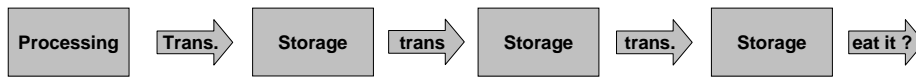


- Continous increase of the consumption of chilled and frozen foods
(BVE 2009, Deutsches Tiefkühlinstitut 2009)
 - Our Industry faces 30% waste from harvest to the consumer while real food prices rose by 64% between 2002 and 2008
(Helms 2010)
 - Much remains to be done to eradicate the scandal of malnutrition in the context of the globalization of the world
(Helms 2010)
- Also inefficient cold chain management leads to these facts!



- There are huge temperature variations in transport vehicles which are often not detected
 - Cold chain interruptions take often place at handover points which are mostly not monitored
 - Monitored temperature data often differ from the products temperature, since the environmental temperature is measured
 - Random measurement of the products temperature at the incoming inspection is not always sufficient
 - The exchange of temperature data over the whole chain is missing, in general no integrated and sufficient systems are implemented
- Misinterpretation and lacks of information lead to inefficient management- and operational decisions in various steps of the cold chain

Food Chain → Supply Chain → Cold Chain



**Challenges: data handling and -interpretation, information management
→ find cost effective decisions and decision-supports-tools**

➔ Principle of Time Temperature Indicators (TTIs):
chemical, physical or enzymatic reactions provide
information in dependency of Time and Temperature

Example:
Response in form of a discoloration (modern TTi)
or melting (an ice-cube, glaciers)



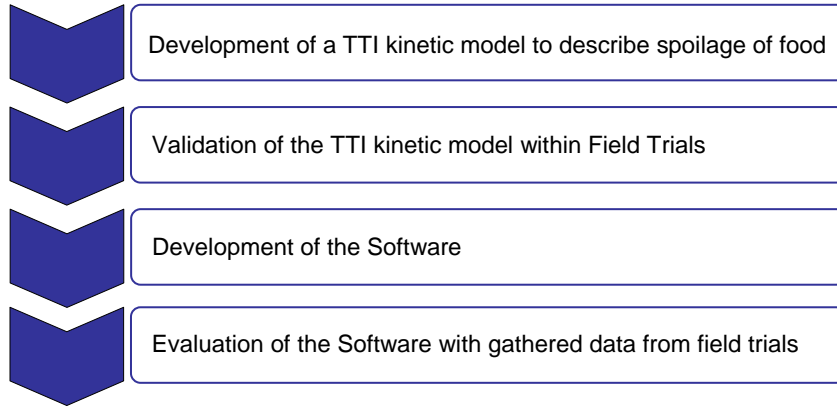
- TTIs provide generally the option to continuously monitor the temperature history along the entire cold chain
(Taoukis and Labuza 1989, Fu and Labuza 1992, Alfaro et al. 2009, Vaikousi et al. 2009)
- TTIs are able to provide indirectly an indication of the freshness of specific products



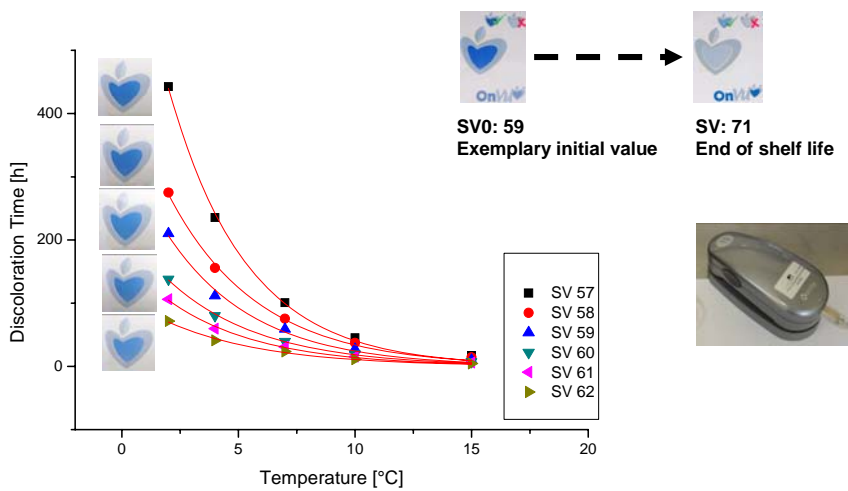
- ➔ Knowledge about the TTI-kinetic in dependency of Time and Temperature
- ➔ Possibility to adjust the TTI-kinetic to the spoilage of your products
- ➔ Cost-Efficiency
- ➔ Electronic readable and storable TTI-information
- ➔ Fast way to correlate the information of the TTI with product-information



The objective of this study was the development of an Internet based **software solution** integrating a **TTI kinetic model** as a **reliable and easy-to-use tool** to support the decision-making within cold supply chains.



Development of a TTI kinetic model





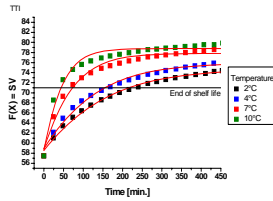
Development of a TTI kinetic model

Laboratory model

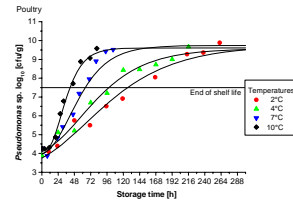


Several studies have been conducted during the last years under isothermal and non-isothermal temperature conditions

TTIs



Growth of *Pseudomonas* sp.



Kinetic behaviour



Description of the kinetic behavior by different functions

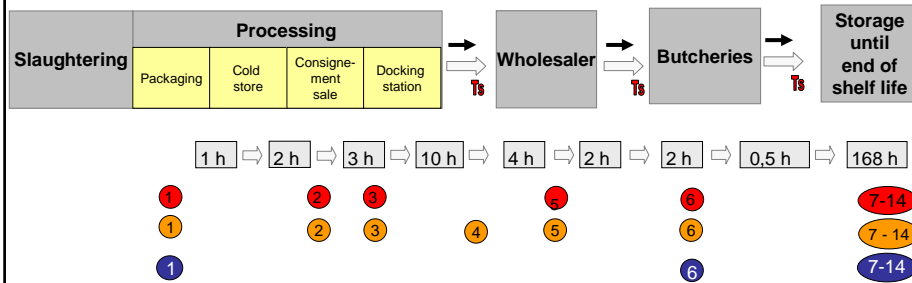
Development of a TTI kinetic model: Kreyenschmidt et al. (2010) and Raab et al. (not published yet)



Validation



Field trial to validate the TTI kinetic model



Integration & measuring points:

- OnVu TTIs
- Microbiological sample
- Temperature logger

- Step in the chain
- T_s Transport step
- Information flow
- x h Sojourn time
- ⇨ Product flow



Features of the software-solution:

- The software allows user-friendly simulations of shelf-lives for dedicated products depending on dynamical and adjustable time-temperature-rows
- It is possible to simulate time and temperature scenarios for real or assumed supply chains
- When the software is used with TTIs, it allows to monitor the cold chain, to estimate remaining shelf life and so e.g. a storage optimization or to rate prices
- Software can be adjusted to different products, to different supply-chains and gives automated action alternatives
- Since the software is programmed with the widely known scripting language php and a mysql-database it is compatible with most servers of commercial internet providers and it can be easily updated and administrated



The screenshot shows the 'Simulate shelf life' section of the CCM-NETWORK website. The page includes a navigation menu, a user login status, and a main form for simulating shelf life. The form contains a table for time and temperature intervals, a product selection dropdown, and a 'calculate shelf life' button. Below the form, there are instructions and background information about the simulation algorithm.

Simulate shelf life

On this page you can simulate the shelf life of specific products in dependency of time and temperature. Please scroll down to get more information and a short instruction manual*.

Interval:	1	2	3	4	5	6	7	8	9	10
Time(h):	30	30	30	1	30	30	30	30	30	30
Temp(°C):	4	5	4	24	4	3	2	3	4	4

choose Product: poultry1
poultry1
pork 2

* To calculate shelf lifes,

- you need to choose a product within the drop-down-box,
- you should enter a timerow that consists out of one to ten different intervals in which the product is exposed to different temperatures. Therefore, enter for each interval its individual duration in hours and its temperature in °C.
- Finally click on the button "calculate shelf life".

Background information

The algorithm bases on many experiments, that mostly have been conducted by the ccm-group of the University of Bonn during the last ten years and that



Mozilla Firefox
<http://www.ccm-network.com/index.php?m=indL>

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CCM-NETWORK

choose Product | poultry1 | calculate shelf life

For this scenario the end of shelf life is expected after **179 h**

The above picture shows the chosen time-row. Time, in degrees of hours, is plotted on the x-axis and the temperature, in degrees of Celsius, on the y-axis.

Your food probably will be spoiled when FI reaches 71:

The above picture shows the "freshness-index" (FI) for the chosen time-row (on the y-axis) in dependency of time (in degrees of hours, plotted on the x-axis). FI is scaled in units that matches to a response function of a Time-Temperature-Indicator (TTI).

- upload new picture
- upload a publication
- post a discussion topic
- offer a job
- post an event
- write an entry to wiki
- invite others
- edit your publications
- edit your job offers
- edit your event-entries
- edit your wiki-entries
- change password
- change your e-mail
- delete your profile

exchange of experience and ideas between research, industry, public authorities and consumers in the field of CCM

- facilitate and establish partnerships for national and international projects
- increase co-operation with partners and experts worldwide
- share ideas and information pertaining to future trends
- demonstrate innovative solutions in the field of Cold-Chain-Management and promote their introduction

benefits for members:

- find experts worldwide in the field of CCM
- introduce yourself
- search and post job listings
- upload or find publications
- post or find events
- discuss innovative ideas and technologies

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- cold-chain-management group of the University of Bonn



Mozilla Firefox
<http://www.ccm-network.com/index.php?m=indR>

Erste Schritte | Aktuelle Nachrichten

CCM-NETWORK

measures response of the TTI with the previous response; the temperature monitoring and freshness control of different products can be improved.

The demonstrated approach was developed for a specific time-temperature indicator. However, it can be easily adopted to various indicators. Additionally, the monitoring tool can be used within different food supply chains. This requires specific adaptations of the software, for example to the kinetics of spoilage of specific products or to specific steps in individual supply chains. Also additional alarm settings as well as actions alternatives can be implemented easily.

Temperature monitoring by using TTIs as a sensor:
 You may use the demonstrator by choosing a product and enter a measured TTI-value.

choose a product: poultry1

measured TTI-value: 60.7

maximum storage temperature: 4

date of packaging (YY MM DD - h - m): 2010 9 20 - 15 0

ALT: Time span in hours after packaging (this overwrites the date of packaging):

[click here to check TTI value](#)

The cold chain was in its limit.

estimated time after packaging (h): **148**

calculated set-point of the TTI: **70.1**

measured TTI-value: **60.7**

residual shelf life in hours, if stored less than 4°C: **144**

The measured TTI-value 148 hours after packaging should be less than 70.1. The residual shelf life can be estimated at least to 144 hours if the future storage temperature will be less than 4°C.

You may calculate other residual shelf lifes for other time-temperature-rows in the future by using the input-form below.

- upload new picture
- upload a publication
- post a discussion topic
- offer a job
- post an event
- write an entry to wiki
- invite others
- edit your publications
- edit your job offers
- edit your event-entries
- edit your wiki-entries
- change password
- change your e-mail
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quality-improvement by using TTIs

aims of the network:

- exchange of experience and ideas between research, industry, public authorities and consumers in the field of CCM
- facilitate and establish partnerships for national and international projects
- increase co-operation with partners and experts worldwide
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The screenshot shows the 'CCM-NETWORK' web application in a Mozilla Firefox browser. The main content area is titled 'Temperature monitoring by using TTIs as a sensor'. It contains a form with the following fields: 'choose a product' (poultry 1), 'measured TTI-value' (63.2), 'maximum storage temperature' (4), and 'date of packaging' (2010-09-20). A 'click here to check TTI value' button is present. Below the form, a green box indicates 'Be carefully, the cold chain was close to its limit.' The results section shows: 'estimated time after packaging (h): 47', 'calculated set-point of the TTI: 63', 'measured TTI-value: 63.2', and 'residual shelf life in hours, if stored less than 4°C: 121'. A text block explains that the measured TTI-value of 47 hours is below the set-point of 63 hours, resulting in a residual shelf life of 121 hours. A sidebar on the right lists 'quality-improvement by using TTIs', 'aims of the network', and 'benefits for members'. A 'Forty' watermark is visible at the bottom left.



The screenshot shows the 'CCM-NETWORK' web application in a Mozilla Firefox browser. The main content area is titled 'Temperature monitoring by using TTIs as a sensor'. It contains a form with the following fields: 'choose a product' (poultry 1), 'measured TTI-value' (64.2), 'maximum storage temperature' (4), and 'date of packaging' (2010-09-20). A 'click here to check TTI value' button is present. Below the form, a red box indicates 'Attention! The cold chain was not ok.' The results section shows: 'estimated time after packaging (h): 47', 'calculated set-point of the TTI: 63', 'measured TTI-value: 64.2', and 'residual shelf life in hours, if stored less than 4°C: 111'. A text block explains that the measured TTI-value of 47 hours is above the set-point of 63 hours, resulting in a residual shelf life of 111 hours. A sidebar on the right lists 'quality-improvement by using TTIs', 'aims of the network', and 'benefits for members'. A 'Forty' watermark is visible at the bottom left.



The measured TTI-value 1000 hours after packaging should be less than 75.8, you measured 67.2. The residual shelf life can be estimated at least to 44 hours if the future storage temperature will be less than 6°C.

You may calculate other residual shelf lifes for other time-temperature-rows in the future by using the input-form below.

TTI-Value:

Interval: 1 2 3 4 5 6 7 8 9 10

Time(h):

Temp(°C):

choose Product: poultry 1

To calculate shelf lifes,

- you need to enter a TTI-start-value, This should be the measured one,
- you need to choose a product within the drop-down-box,
- you should enter a timerow that consists out of up to ten different intervals in which the product is exposed to different temperatures. Therefore, enter for each interval its duration in hours and its temperature. In total you should not exceed 5000 hours.
- Finally hit the button "calculate shelf life".



For this scenario the end of shelf life is expected after 44 h
Your food probably will be spoiled when FI reaches 71:

Background information

The algorithm bases on many experiments, that mostly have been conducted by the ccm-group of the University of Bonn during the last ten years and that are still ongoing. The experiments focus on different topics, that can be classified as follows:

- Experiments to investigate the microbiological growth of bacteria under different environmental conditions,
- experiments to investigate the change of sensory parameters in dependency of time and temperature,
- experiments to determine correlations between the microbiological and sensory parameters,
- experiments to investigate, whether specific TTIs (Time Temperature Indicators) show a similar behaviour in its kinematics like specific food and whether specific TTIs can be initialized for specific food products,
- experiments to determine product specific thresholds that indicate the end of the shelf life in form of sensory and microbiological parameters as well as color-values of the investigated TTIs.



Application in real cold supply chains

- The field tests showed the applicability and usefulness of the internet based software solution
- Allows an economical integration of the TTIs into temperature monitoring systems
- Enhances the possible spectrum of applications by using TTIs together combined with software
- Flexible integration according to the structure of international food chains



Thank you for your attention!

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