Time temperature integrator/indicator (TTI): photochromic/photochemical TTI

UV color TTI

Identification

Key words  
- time-temperature indicator, TTI, cold chain, photochromic, printable, UV light, charging time, shelf life, pTTI

Latest version  
- 2012/12/07

Completed by  
- INRA - IATE, KU Leuven LFT

How does it work?

Primary objective  
- Monitor the impact of the temperature evolution of a fresh product all along the cold chain (from production over distribution and storage to the actual use).
**Working principle**

Monitoring the cold chain is a key point in food industry. The current temperature measurement methods, such as random in-site measurement or RFID, present one main disadvantage: the monitoring stops at the retailer. Time Temperature indicators/integrators (TTIs) enable continuous and cumulative monitoring of the impact of temperature changes that affect a fresh food product from production over distribution and storage to the actual use (consumption) (7)(8). TTIs are defined as simple, inexpensive devices that cumulatively indicate the temperature history and quality status of the food they are attached to. This indication is possible through an easily measurable and irreversible change that depends on both time and temperature, (11). By use of such TTIs, reliable estimation of the quality status and the remaining shelf-life can be performed, allowing better management and optimisation of the cold chain from production to the point of consumption (12).

There are several different TTI systems available. The principle of most of the TTIs is based on enzymatic, chemical, mechanical, electrochemical or microbiological reactions which result in a colour change of the label in a rate that is temperature dependent (11).

For the implementation of a TTI system as temperature and quality control tool in the food chain, it has to satisfy certain requirements (11)(13):

- **Kinetics**: mathematical models are needed that describe the effect of temperature on the evolution of the quality status of the food product as well as on the TTI response under dynamic storage conditions. For ideal prediction, the food quality target attribute and the TTI response have the same activation energy (i.e. same temperature dependency of the reaction rate constants). To act as a reliable food label, the difference in activation energy between the TTI and the monitored food aspect should be as small as possible (preferably < 5 kcal/mol) (1).
- **Useful response period**
- **Long shelf life before activation**
- **User-friendly handling and read-out**
- **Nontoxic**
- **Cost effective**

As TTIs are usually implemented as tags on the product package with very simple read-out (mainly visual indicators), the end consumer is able to get the information by himself and decide whether or not he is going to buy/consume it.

The present specific TTI is based on a photochromic/photochemical solid state reaction (1)(2): the specific molecule is colourless at basic state; it becomes dark blue when activated by exposure to ultra-violet (UV) light; it reverts to colourless depending on the temperature (under an Arrhenius equation).

The tag must be concealed under an anti-UV filter (e.g. Thermal Transfer Ribbon) after activation to avoid inappropriate re-charging by light, in particular UV light. Consequently, if the tag on the package is dark blue to light blue when the end consumer is willing to eat the product, it is right; if the tag is light grey or white, the product should not be consumed.

**Images**

**Additional effects**

The shelf life of the TTI can be adjusted by changing the initial charging time (specific tables).

The printed tags can be stored at room temperature, but in the dark, until they are charged for use. (1)(2)

**Important process parameters**

The support paper needs to be specified. Printing on plastic substrates is also possible (BOPP).

The ink thickness is not easy to measure, but this parameter is indirectly checked by activation and colour measurement. Charging time.

**Important product parameters**

Distance/space between the product and the package: close contact is recommended. If not possible for technical or aesthetic reasons, it should be minimized, as it is important that the food product and the TTI experience the same temperature history.
What can it be used for?

**Products**
This TTI can be used for any fresh products, particularly fresh and cooked meat, poultry and fish, and ready-to-eat food, packed under vacuum, or normal or modified atmosphere (1), drinks (e.g. fresh milk, fresh juices).

**Operations**
Packaging

**Solutions for shortcomings**
Cold chain management during distribution and storage
Optimisation of stock rotation
Reduction of waste
Low-cost TTI

What can it NOT be used for?

**Products**
Dry, long shelf-life products (>14 days at 4 °C)

**Operations**
Other operations than cold-chain monitoring through packaging

**Other limitations**
The colour references are not so instinctive for the consumer: blue = (still) good vs. light grey/transparent = not good.
Illegal activities, e.g. re-packing of expired food and labelling as “fresh”, cannot be avoided, but become less attractive due to additional cost for TTI labels.

**Risks or hazards**
No risks known. Migration of new components was tested and is no issue (food packaging compliant).

Implementation

**Maturity**
This technology has been internationally patented for fresh cut meat and fish applications.
This technology has already been implemented at industrial scale and the manufactured tags are commercially available for the 14-days lasting version.
The 1-month lasting version is at lab scale.

**Modularity/Implementation**
This technology is supplementary to the current time-temperature measurement devices. It enables to visually control if the individual food packaging was stored correctly (not possible with data loggers).
Consequently, a food processing industry can carry on using their tag sticking equipment; tag manufacturers may have to change some of their production devices. Yet, specific application equipment is required: UV activation, filter transfer.

**Consumer aspects**
A small test has been carried out on 5 consumers: it was concluded that on a perception level, the currently manufactured tags (OnVuTM brand) “state the intended message clearly”, meaning they can be easily read, under a convenient design. (2)
On a general level, the benefit of TTIs for the consumer is positive: easy to use, food safety, reduction of food waste.

**Legal aspects**
Patent: WO99/39197
European legislation:
- food packaging: regulation (EC)1935/2004

**Environmental aspects**
No impact known.
Facilities that might be interesting for you

Further Information

<table>
<thead>
<tr>
<th>Institutes</th>
<th>University of Bonn, NTU Athens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies</td>
<td>SNIV, SOMAFER, BASF</td>
</tr>
</tbody>
</table>
3. Austrian Research Institute for Chemistry and Technology (OFI). Test report: evaluation of the functionality of Ciba’s TTI.  