Food Chain Quality Management by Time-Temperature Integrator Technology

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- Food Chain Quality Management
- Time-Temperature Integrator Technology
FOOD CHAIN

http://www.cdc.gov/foodsafety/outbreaks/investigating-outbreaks/figure_food_production.html
FOOD CHAIN

- GROWER
- PROCESSOR
- WHOLESALER
- RETAILER
- CONSUMER
FOOD CHAIN – QUALITY MANAGEMENT

- GROWER
- PROCESSOR
- WHOLESALER
- RETAILER
- CONSUMER

ISSUES ➔ KNOWLEDGE

DIFFERENCE ➔ APPROACH

Quality capacity

Know

LEDGE

TOOL

capacity

- OK?
FOOD LOSS AND WASTE IN VALUE CHAIN

Share of Total Food Loss and Waste by Stage in the Value Chain, 2009
(100% = 1.5 quadrillion kcal)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Developing Countries</th>
<th>Developed Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>14%</td>
<td>10%</td>
</tr>
<tr>
<td>Handling and Storage</td>
<td>24%</td>
<td>9%</td>
</tr>
<tr>
<td>Processing and Packaging</td>
<td>24%</td>
<td>4%</td>
</tr>
<tr>
<td>Distribution and Market</td>
<td>12%</td>
<td>7%</td>
</tr>
<tr>
<td>Consumption</td>
<td>35%</td>
<td>28%</td>
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</tbody>
</table>

Note: Number may not sum to 100 due to rounding.

Figure 3 | Share of Global Food Loss and Waste by Region, 2009 (100% = 1.5 quadrillion kcal)

- **Industrialized Asia**: 28%
- **South and Southeast Asia**: 23%
- **North America and Oceania**: 14%
- **Europe**: 14%
- **Sub-Saharan Africa**: 9%
- **North Africa, West and Central Asia**: 7%
- **Latin America**: 6%

Note: Number may not sum to 100 due to rounding.


Figure 2 | Share of Commodity Lost or Wasted, 2009 (Percent of kcal)

Note: Values displayed are of waste as a percent of food supply, defined here as the sum of the “Food” and “Processing” columns of the FAO Food Balance Sheet.

Source: WRI analysis based on FAO 2011.
Reducing Expiration Date Confusion

“Use by” and “best by” dates, commonly found on both perishable and nonperishable products, are manufacturer suggestions for peak quality. They do not indicate food safety, as is commonly believed, nor are they regulated. The exception to this is infant formula, for which “use by” dates are federally regulated, and some other specific products in certain states.

This is generally not how consumers interpret these dates. Many people believe they indicate a product’s safety and discard food as soon as it reaches its expiration date."
Time based management

Technology at present

Best by: 02 12 57

Sell by: 02 08 57

Lot: 245845
(International Institute of Refrigeration, 2008)
Time based management
Food chain quality management

- Post Harvest
  - Raw material management
- Manufacturing
  - Production management
- Post manufacturing
  - Inventory management
  - Distribution management
- Along Food chain
  - Traceability
Assumption

All products of the same lot/batch have same quality & same degradation rate

Same Expiration Date !!!
Time-based: Post harvest management

- **Raw material management**
  - **Criteria:** harvest time
  - **Tools:** Harvest Batch Number, Lot number
  - **Issue policy:**
    - First-In First-Out; Least expired goods
    - First-In Last-Out; Premium goods
Time-based: Manufacturing management

**Product management**

- **Criteria:** Batch or Lot, Process time
- **Tools:** Process Batch Number, Lot number, Process time (constant)
- **Issue policy:**
  - First-In First-Out ; Least expired goods
  - First-In Last-Out ; Premium goods
Time-based: Post manufacturing management

- **Inventory management**
  - **Criteria:** Product Lot/time
  - **Tools:** Product Lot number
  - **Issue policy:**
    - First-In First-Out; Least expired goods
    - First-In Last-Out; Premium goods
Time-based: Post manufacturing management

❖ Distribution management

❖ Criteria: Shortest route & time

❖ Tools: Vehicles, Customers location information, Maps

❖ Issue policy: Location grouping, Orders Management

❖ First-In First-Out ; Least expired goods

❖ First-In Last-Out ; Premium goods
Assumption

All products of the same lot/batch have the same quality & the same degradation rate

Same Expiration Date !!!

Problem in practice

Each product item undergoes different environmental conditions

(temperature, humidity, light, oxygen, etc.)
Time based management

Simple but Problematic
Drawer/Door Openings

Adande vs. Competitor unit - Temperature stability during consecutive drawer/door openings

http://www.adande.com/Payback-Benefits.htm
BOILING WATER

VERY HOT WATER

FOOD KEPT HOT

FOOD KEPT WARM

BLOOD TEMPERATURE

ROOM TEMPERATURE

FREEZING WATER

DANGER ZONE - 5°C - 60°C

SPORES SURVIVE

BACTERIA DIE

BACTERIA START TO DIE

TOO HOT FOR COMFORT BUT BACTERIA WILL GROW

IDEAL FOR BACTERIA GROWTH & REPRODUCTION

BACTERIA GROW WELL

BACTERIA AT REST

Source of contamination

Transfer of bacteria

Potentially hazardous foods

Time and warmth allows bacteria to grow

Food eaten

Food poisoning

STORAGE LIFE

PRODUCE

DAYS

BOX TEMPERATURE

http://www.pacificseabreeze.com/tech-library/foodstoretemp/storagelife.htm
Food Chain Quality Management

What technology???

at present

Time-based

Future trend

Quality-based
Assumption

- Time based

All products of the same lot/batch have the same quality & same degradation rate.

Temperature is the most critical parameter governing degradation rate of food.

Problem in practice

Each product item undergoes different environmental conditions (temperature, humidity, light, oxygen, etc.).

Same Expiration Date !!!
Diagram of Sophisticated Packaging System

Intelligent packaging

Diagnostics

Bacteria
Temperature
Time
Quality
Sterilisation
Ripeness
Ethylene
Etc.

EAS

Anti-theft
Stock control
Etc.

RFID

Very wide range of benefit and application

Other printed or laminated electronic in due cause

Sophisticated packaging

Active packaging

Hurme (2003)
Temperature-Time Integrator/Indicator (TTI)

Small + inexpensive devices
Small tag on individual packaging

Measurable, time-temperature dependent change that reflects the temperature history of food products
Sense & accumulate temperature history during distribution and storage

(Taoukis and Labuza, 1989; Taoukis and Labuza, 2003)
Temperature-Time Integrator/Indicator (TTI)

Provide indirectly information about the product quality and the storage condition of the package. 
Show real-time remaining shelf-life of product which affected by temperature

Visible/sensible characteristic change
Not require an additional reader device
Can be used as traceability information

(Taoukis and Labuza, 1989; Taoukis and Labuza, 2003)
TTI: Time Temperature Integrator/Indicator
Quality-based Principle

Initial Quality

End Quality

Expired = 6th

A
Ideal Conditions

B
Temperature Abuse

Expired = 4.4th
Current TTI Systems: Various Technologies

- Diffusion-based
- Enzyme-based
- Bacterial-based
- Polymer-based
- Photochromic-based
Diffusion-based TTIs

- MonitorMark TTI is an indicator dependent on the diffusion of a colored fatty acid ester along a porous wick made of high quality blotting paper.

The diffusion of a dye is used as an indicator.
Enzyme-based TTI

• VITSAB® TTI is based on a color change induced by a drop in pH resulting from the controlled enzymatic hydrolysis of a lipid substrate.
Polymer-based TTIs

- Fresh-Check TTI is based on temperature dependent polymerisation reactions in which diacetylene crystals polymerise via 1,4 addition polymerisation to a highly colored polymer.

Fresh-Check® (LLT)
Cryolog’s Traceo and eO labels are based on food grade micro-organisms, which behave in the same way as the micro-organisms responsible for the deterioration of the product.
• The OnVu™ TTI is based on the inherent reproducibility of reactions in photosensitive compounds. It is activated by UV light first to become dark blue and then gradually changes to light color as time passes.
Types

Gradually color changing with a color reference chart & explanation

Self-reading with a long induction period

(Gordhan, nd)
After UV

(Nopwinyuwong et al., 2012b)
Adding Amphiphilic Polymer (AP)

The concept of preparation “PDA vesicle/amphiphilic polymer”

PCDA → PCDA vesicles → PPCDA vesicles

Amphiphilic Polymer (AP) → Hydrophobic segments

PDA/AP after heating

(Nopwinyuwong et al., 2012a)
Considerations for the Application of Time-Temperature Integrators in Food Distribution

Summary

The use of TTIs is currently being considered by many manufacturers and the USDA as a means to monitor or predict food safety and shelf life based on the temperature history of the food. With the principles and methodology discussed in this paper, one should be able to decide whether one should employ a TTI tag for a particular food, how to choose a TTI tag properly, how to calculate the effective temperature for a variable time-temperature distribution, how to correlate the TTI response with food quality or shelf life, and how to calculate the quality loss or shelf life remaining correctly.
## Time-temperature indicators (TTIs)

P. S. Taoukis, National Technical University of Athens, Greece and T. P. Labuza, University of Minnesota, USA

<table>
<thead>
<tr>
<th>Date</th>
<th>Inventor</th>
<th>Principle of operation</th>
<th>Patent No</th>
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<tbody>
<tr>
<td>1991</td>
<td>Jalinski, T.J.</td>
<td>Chemical (TTI)</td>
<td>US5,182,212</td>
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<td>Thiera, Th.</td>
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<td>Swearson, W.</td>
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<td>Loebel, J.</td>
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<td>Veis, V.</td>
<td></td>
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<td>2000</td>
<td>Ram, A.T.</td>
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<td>US6,103,351</td>
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<td>2000</td>
<td>Bray, A.V.</td>
<td>Physical (TTI)</td>
<td>US6,158,381</td>
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<td>2001</td>
<td>Qiu, J.</td>
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<td>US6,244,208</td>
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<td>2002</td>
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<td>-----------------------</td>
<td>------------</td>
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<td></td>
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<tr>
<td>Quality/safety at the beginning</td>
<td>All same</td>
<td>All same</td>
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<tr>
<td>Quality/safety change rate</td>
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<td>Temperature dependent</td>
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<td>Issue policy</td>
<td>First-In-First-Out (FIFO)</td>
<td>Least-Shelf-life-First-Out (LSFO)</td>
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<td>Last-In-First-Out (LIFO)</td>
<td>Most-Shelf-life-First-Out (MSFO)</td>
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<tr>
<td>Decision</td>
<td>EXP. Date</td>
<td>Shelf-life/quality remaining</td>
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TTI and Food Management

Least Shelf-Life First Out (LSFO) issuing policy

i) Reduce waste

ii) More product consistency (same quality level)

(Giannakourou & Taoukis, 2003)
Survey: Freshness indicator on fresh meat & bagged salad package

✓ ~76% would switch into new brand with TTI
✓ 95% felt indicator provide a safety advantage
✓ 88% felt indicator provide a freshness advantage
# Consumer Attitudes

(Fortin et al., 2009)

<table>
<thead>
<tr>
<th>Offer Amount</th>
<th>Willing to pay (%yes)</th>
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<tr>
<td></td>
<td>Meat</td>
<td>Salad</td>
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<tr>
<td>$0.05</td>
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<td>$0.10</td>
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<td>$0.15</td>
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<td>53.97</td>
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<td>$0.20</td>
<td>71.19</td>
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<td>$0.25</td>
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</table>
Quality monitoring and management during storage and distribution of frozen vegetables
Waraporn Boonsupthip, Dennis R. Heldman and Jinnipar Choachamnan

Research point of view

Gradual change in colors

Present

Day 0

Expiration Date

Challenge

Quality monitoring and management during storage and distribution of frozen vegetables
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<table>
<thead>
<tr>
<th>TTI</th>
<th>Mechanism</th>
<th>cost per unit</th>
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<tbody>
<tr>
<td>3M™ MonitorMark™ Time Temperature Indicator 9861A, 10°C/50°F, Record Time 2 Weeks</td>
<td>dye diffusion</td>
<td>$2.78</td>
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<td>3M™ MonitorMark™ Time Temperature Indicator 9860B (5°C/41°F) 48 hours</td>
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<tr>
<td>3M™ Freeze Watch™ Indicator 9800FW (-4°C) (25°F)</td>
<td>dye diffusion</td>
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<td>ColdMark 0°C / 32°F</td>
<td>-</td>
<td>$2.05</td>
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<tr>
<td>WarmMark Duo 10°C &amp; 34°C</td>
<td>-</td>
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<tr>
<td>OnVu™</td>
<td>Photosensitive compound</td>
<td>few cents</td>
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<tr>
<td>Lifelines' Fresh Check</td>
<td>polymerization</td>
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</tr>
<tr>
<td>Seafood Indicator</td>
<td>-</td>
<td>$1.00</td>
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</table>

References:
http://www.shop3m.com/3m-monitormark-time-temperature-indicator-9861a.html
http://www.tgoldkamp.com/3m-freeze-watch-indicator-9800fw-4-c-25-f.html
http://www.ift.org/~/media/Knowledge%20Center/Science%20Reports/Research%20Summits/Packaging/Packaging_ActiveIntelligentPackaging_Brody.pdf
http://buy.shockwatch.com/Seafood-Indicator/dp/B00K7HWPS6
Would TTI be used for Your food chain quality management?
Thank you for your attention.

Any Questions