| 1. | Intelligent food packaging       |
| 2. | Time-Temperature Indicator       |
| 3. | Freshness Indicator              |
| 4. | Applications of TTI in food industry |
| 5. | Indicator applications in Korea  |
| 6. | Introduction of the Center for Intelligent Agro-food Packaging |
Intelligent food packaging

Smart (intelligent) packaging: a mode of packaging that is capable of carrying out intelligent functions to facilitate decision making to extend shelf life, enhance safety, improve quality, provide information, and warn about possible problems.
1. Smart packaging

Time temperature indicator

Freshness Indicator

TTI applications

In Korea

Center for Intelligent Agro-Food Packaging

**World market**

**Figure 1.1. Global Active, Intelligent and Smart Packaging Applications in the Food and Drink Market by Value 2011, 2016 & 2021**

<table>
<thead>
<tr>
<th>Year</th>
<th>Global Sales (US$ bn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>11.7</td>
</tr>
<tr>
<td>2016</td>
<td>17.23</td>
</tr>
<tr>
<td>2021</td>
<td>24.65</td>
</tr>
</tbody>
</table>

**Source: Visongain 2011**

**Figure 2.1. Submarket Share by Application of the Global Active, Intelligent and Smart Food & Drink Packaging Market 2011 (%)**

- **Active Packaging**: 50%
- **Smart Packaging**: 35%
- **Intelligent Packaging**: 15%

**Source: Visongain 2011**

2011년 117억 달러,
2016년 172.3억 달러,
2021년 246.5억 달러 예상

2011년 전체 지능형 포장 시장에서
active 포장 50%, smart 포장 35%,
intelligent 포장 15% 차지
1. **World market**

![Gartner Hype Cycle – Food Packaging](image)

- **Smart packaging**
- **Time temperature indicator**
- **Freshness Indicator**
- **TTI applications**
- **In Korea**
- **Center for Intelligent Agro-Food Packaging**
TTI changes in color according to time-temperature history. This color change indicates the change in quality of the accompanied food.
# TTI types and their characteristics

<table>
<thead>
<tr>
<th>Product</th>
<th>Principle</th>
<th>Types of response</th>
<th>Use–by date</th>
<th>( E_A ) (kJ/mol)</th>
<th>Activatable</th>
<th>Price (cents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CheckPoint® Types M, L (Vitsab, Sweden)</td>
<td>Enzymatic</td>
<td>green to yellow to red</td>
<td>hours to weeks at 4°C</td>
<td>70 ~ 170</td>
<td>Yes</td>
<td>5 ~ 15</td>
</tr>
<tr>
<td>Fresh-Check® (Temptime, USA)</td>
<td>Polymeric</td>
<td>colorless to blue</td>
<td>hours to weeks at 4°C</td>
<td>80 ~ 90</td>
<td>No</td>
<td>1 ~ 5</td>
</tr>
<tr>
<td>OnVu TM (Ciba Specialty Chemicals, Switzerland)</td>
<td>Photochemical</td>
<td>dark blue to colorless</td>
<td>hours to weeks at 4°C</td>
<td>90 ~ 150</td>
<td>Yes</td>
<td>1 ~ 5</td>
</tr>
<tr>
<td>TT SensorTM (Avery Denison, USA)</td>
<td>Diffusion</td>
<td>yellow to pink</td>
<td>hours to weeks at 4°C</td>
<td>115 ~ 125</td>
<td>Yes</td>
<td>5 ~ 15</td>
</tr>
<tr>
<td>eO (Cryolog, France)</td>
<td>Microbiological</td>
<td>green to red</td>
<td>hours to weeks at 4°C</td>
<td>100 ~ 110</td>
<td>No</td>
<td>5 ~ 15</td>
</tr>
</tbody>
</table>
2. Commercial TTI products

- **Smart packaging**
- **Time temperature indicator**
- **Freshness Indicator**
- **TTI applications**
- **In Korea**
- **Center for Intelligent Agro-Food Packaging**

Enzyme TTI

Polymer TTI

Diffusion TTI
2. Commercial TTI products

Smart packaging

Time temperature indicator

Freshness Indicator

TTI applications

In Korea

Center for Intelligent Agro-Food Packaging

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Microbial TTI

Photochemical TTI

TTI applications

In Korea
2. Requirements for high quality TTI

TTI’s requirements:
- Accuracy in the quality predictions
- High visibility
- Irreversible change in color
- Easy activation
- Easy handling and storage before use
- Small size and low price

Smart packaging
Time temperature indicator
Freshness Indicator
TTI applications
In Korea
Center for Intelligent Agro-Food Packaging
How to predict the food quality from TTI

(Food Process Modelling, 2001. pp. 402-432)
## Activation energies for different spoilage mechanisms for seafood

<table>
<thead>
<tr>
<th>Species</th>
<th>Mechanism</th>
<th>Ea (KJ mol$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh fish fillet</td>
<td>Spoilage</td>
<td>~84–125</td>
</tr>
<tr>
<td>Fresh fish fillet</td>
<td>Toxins</td>
<td>~50–84</td>
</tr>
<tr>
<td>Boque</td>
<td>(<em>Pseudomonas</em> spp.)</td>
<td>81.6±11.6</td>
</tr>
<tr>
<td>Boque</td>
<td>(<em>Shewanella putrefaciens</em>)</td>
<td>82.7±11.1</td>
</tr>
<tr>
<td>Cod fillet</td>
<td>Spoilage</td>
<td>42.3</td>
</tr>
<tr>
<td>Cod fillet</td>
<td>Toxin</td>
<td>60.7</td>
</tr>
<tr>
<td>Whiting fillet</td>
<td>Spoilage</td>
<td>29.3</td>
</tr>
<tr>
<td>Whiting</td>
<td>Toxin</td>
<td>48.6</td>
</tr>
</tbody>
</table>
Values of activation energy ($E_a$) for different processes occurring in fruits and vegetables

<table>
<thead>
<tr>
<th>Product</th>
<th>Q</th>
<th>$E_a$ (KJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shredded</td>
<td>Respiration rate</td>
<td>79</td>
</tr>
<tr>
<td>Sliced</td>
<td>Respiration rate</td>
<td>70</td>
</tr>
<tr>
<td>Whole</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Onion</td>
<td>Respiration rate</td>
<td>35</td>
</tr>
<tr>
<td>Mushrooms</td>
<td>Color change</td>
<td>63</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Color change</td>
<td>37</td>
</tr>
<tr>
<td>Strawberry</td>
<td>Firmness loss</td>
<td>39</td>
</tr>
<tr>
<td>Fresh apple</td>
<td>Respiration rate</td>
<td>29</td>
</tr>
</tbody>
</table>
Freshness Indicator (FI)

As a subclass of intelligent packaging, a food spoilage indicator is a packaging system (or material) which uses metabolites as “information” to monitor the status of food spoilage.
## Comparisons of the respective advantages and disadvantages of TTIs and FQIs

<table>
<thead>
<tr>
<th>Time-temperature indicators</th>
<th>Food quality indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>Easily read</td>
<td>Do not directly indicate actual Seafood quality</td>
</tr>
</tbody>
</table>
| Accepted quality assurance method, commercially available, cheap unit cost science understood-maturing technology | | Directly indicate quality/spoilage potentially cheap | • Restrictions on formulation  
• Difficult to apply |

(Smart Packaging Technologies. 2008. pp. 75-92)
Postmortem changes in fish meat
### Summary of the Freshness indicating metabolites and indicator concepts available for their detection

<table>
<thead>
<tr>
<th>Quality indicating metabolite</th>
<th>Corresponding food types</th>
<th>Commercial freshness indicating products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>Seafood, Fresh produce</td>
<td></td>
</tr>
<tr>
<td>Organic acids</td>
<td>Fresh fish, Meat, Poultry</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>Meat</td>
<td></td>
</tr>
<tr>
<td>Volatile nitrogen compounds (e.g. ammonia, dimethylamine, trimethylamine)</td>
<td>Seafood</td>
<td>Fresh Tag (Cox Recorders, USA)(previously available)</td>
</tr>
<tr>
<td>Biogenic amines (e.g. tyramine, cadaverine, putrescine, histamine)</td>
<td>Poultry, Beef, Pork</td>
<td>FreshQ (Food Quality Sensor International, Inc., USA)</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Indication of microbial growth in several food types</td>
<td>For appropriate level of CO₂ in MA-packages (Sealed Air, USA previously available)</td>
</tr>
<tr>
<td>ATP degradation products</td>
<td>Meat, especially seafood</td>
<td>Transia GmbH (Germany) test strips</td>
</tr>
<tr>
<td>Sulfuric compounds</td>
<td>Poultry meat, Seafood</td>
<td>Freshness Guard Indicator (UPM Raflatac, Finland)</td>
</tr>
<tr>
<td>Undefined volatiles</td>
<td>Meat</td>
<td>It’s Fresh™ (It’s Fresh! Inc.) (concept for consumers own use)</td>
</tr>
<tr>
<td>Microbial enzymes</td>
<td>Not specifically defined, several</td>
<td>Toxin Guard™ (Toxin Alert Inc., Canada)</td>
</tr>
<tr>
<td>Pathogenic bacteria</td>
<td>Not specifically defined, several</td>
<td>Food Sentinel System™ (Sira Technologies, USA)</td>
</tr>
</tbody>
</table>

Correlation between tyramine and aerobic mesophilic bacterial counts during the storage of broiler chicken cuts.

3. Smart packaging

Time temperature indicator

Freshness Indicator

TTI applications

In Korea

Center for Intelligent Agro-Food Packaging

Change in color of indicator label in response to CO₂

Packaged golden drop with food spoilage indicator label. green = fresh; orange = warning

[Talanta. 2010. 81(3): 1126-32]
Commercial FI products

SensorQ™ Smart Label
(Food Quality Sensor International, Inc. USA)

< food-borne bacteriological levels >

Freshness watchdog (Japan)

< ammonia >
Commercial FI products

**Smart packaging**

**Time temperature indicator**

**Freshness Indicator**

**TTI applications**

**In Korea**

**Center for Intelligent Agro-Food Packaging**

Food Freshness Indicator (FFI) (It’s Fresh® UK)

<amines and sulphides>

Strathclyde University (UK)

<oxygen>
Commercial FI products

- Smart packaging
- Time temperature indicator
- Freshness Indicator
- TTI applications
- In Korea
- Center for Intelligent Agro-Food Packaging
Sample of TTI’s applications (cold chain management)

SMAS (Safety Monitoring and Assurance System : FIFO (First-In/First-Out)

- Design of the field test for pork cuts products.

(Smart Packaging Technologies. 2008. pp. 61-74)
Measured lactic acid bacteria log counts for each date of microbiological analysis for all 72 samples (* hours after the split)
Distribution of the remaining shelf life of meat products at the time of consumption with FIFO and SMAS approach.
Indicator applications in Korea

- **Smart packaging**
- **Time temperature indicator**
- **Freshness Indicator**
- **TTI applications**
- **In Korea**

**Center for Intelligent Agro-Food Packaging**

**TTI applications in Korea**

- **티티아이사 - sTTI**
  - 패키지의 식품과 유제품류, 두부, 계란 등 냉장유통 식품의 관리에 이용
  - Source: 급식뉴스 (http://www.newsfs.com)

- **프레시포인트코리아㈜ - CoolVu Thaw&Sell**
  - 냉동보관하다 냉동해제 뒤 판매하는 신선식품의 현재 상태를 알려줌
  - Source: 중도일보
[현장 적용 및 시범사업]
1. 기업명: 경기농협식품조합공동법인(오색소반 김치)
2. 기술이전 명: 지능형 포장 IT용 리벨 상품, 지능형 유통관리시스템 상품
3. 진행상황: 참여기업체에 시범적용 중
현장, 요식업업체들의 동하여
TTI가 부착된 김치 상품 판매 예정

<table>
<thead>
<tr>
<th>김치 생산공장</th>
<th>소매점(학교)</th>
<th>대리점</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 김치 생산</td>
<td>10. 하차 및 김지 수령</td>
<td>6. 하차 및 냉장고 입고</td>
</tr>
<tr>
<td>2. 냉장고 입고</td>
<td>9. 소매점 배송</td>
<td>7. 보관</td>
</tr>
<tr>
<td>3. 보관</td>
<td>8. 냉장고 출고 및 상자</td>
<td></td>
</tr>
<tr>
<td>4. 냉장고 출고 및 상자</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. 대리점 배송</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Indicator applications in Korea

Smart packaging

Time temperature indicator

Freshness Indicator

TTI applications

In Korea

Center for Intelligent Agro-Food Packaging
2010 Agriculture Research Center (ARC)

An Overview of Research

지능형 농식품 포장연구센터

FOR INTELLIGENT AGRO-FOOD PACKAGING CENTER
What is ARC?

It stands for Agriculture Research center.

It was founded in 2010 by Korean Ministry of Agriculture.

It will be supported with the research funds for 10 years.

The center purposes:
To develop the innovative technology for the intelligent food packaging,

To establish the new IFP industries in Korea.
지능형 포장 시스템

지능화 목표: 포장식품의 소비・유통・저장을 최적으로 관리

외장/내장 지시계
아날로그 정보제공

포장재/용기
포장식품 보호

RFID기반 식품포장
디지털 정보제공

IT 기반 포장유통 시스템
포장식품 유통관리
Background

Outline of Research
2010 Agriculture Research Center (ARC) An Overview of Research and Vision of CIFP

1.2 단계
기술개발 참여대학

농림축산식품부
농림수산식품
기술기획평가원

지능형 능식품 포장 연구센터
Industry - University - Government collaboration

기술개발 참여업체

3 단계
시간-온도 이력시계 분야
신선도 지시계 분야
포장·유통 시스템 분야
RFID-지시계 분야
기능성 포장용기 분야
기능성 포장재 분야

지능형 포장 제조업체

구매업체 A
구매업체 B
구매업체 C
구매업체 D
구매업체 E
구매업체 F
구매업체 G

시장
지능형 농식품 포장 개발

제 1 핵심
1-1 포장외장지시계 시간-온도이력지시계
1-2 포장내장지시계 식품품질지표지시계, O2 및 CO2 지시계

제 2 핵심
2-1 RFID-전기센서
2-1 RFID-지시계
2-2 RFID/USN 시스템

제 3 핵심
3-1 지능형 포장재
3-2 지능형포장시스템

Outline of Research
2010 Agriculture Research Center (ARC) An Overview of Research and Vision of CIIFP
Thank you for your attention

2010 Agriculture Research Center (ARC)