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Poznań University of Economics and Business

**Poznań** – the 5th largest city in Poland (ca. 520 000 habitants) / **Poznań** metropolitan area – 1,1 mln
- a very important center of trade, technology, sports, tourism, and education (ca. 130 000 students)
(8 public universities: Adam Mickiewicz Univ. (universal), Universities of Medical Sciences, Technology,
Life Sciences, Music, Fine Arts, Physical Education and Economics & Business

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Our university awarded with the international Business School Impact System (BSIS IMPACT) certificate
Mariusz Tichoniuk

Poznań University of Economics and Business

Programs:
- Bachelor in Business Administration – English language course
- Finance (Bachelor) – English l. c.
- Innovation Management (Master) – English l. c.
- International Economic Relations (Master) – English l. c.
- Quantitative Finance (Master) – English c.
- Doctoral School / Doctoral Seminars in English
- Product Quality and Development (Engineer / Master) – Polish language course
- Production Management and Engineering (Eng. / Master) – Polish l. c.
THE POTENTIAL OF INTELLIGENT PACKAGING IN THE REDUCTION OF FOOD WASTE

According to FAO reports one-third of all food produced for human consumption is lost or wasted. The estimated total cost is 990 billion USD every year around the world. For the European Union, ca. 88 million tons of food is wasted every year (173 kg per person).

The main source of food waste in the food supply chain is improper household storage and consumption.
<table>
<thead>
<tr>
<th>Reasons for food loss/waste</th>
<th>Packaging opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Packaging failure in distribution</td>
<td>Fit for purpose</td>
</tr>
<tr>
<td>2. Food perishing in distribution and after sale</td>
<td>Pre-packed or processed food</td>
</tr>
<tr>
<td>3. Confusion about shelf life and food safety</td>
<td>Packaging materials and innovation to extend shelf life</td>
</tr>
<tr>
<td>4. Packaging failure/damage in transit</td>
<td>Designing for smaller household</td>
</tr>
<tr>
<td>5. Excess stock</td>
<td>Date marking</td>
</tr>
<tr>
<td>6. Poor stock rotation</td>
<td>Understanding and tracking supply chain losses</td>
</tr>
<tr>
<td>7. Multiple handling of fresh produce</td>
<td>Intelligent packaging and data sharing</td>
</tr>
<tr>
<td></td>
<td>Retail ready packaging (RRP)</td>
</tr>
</tbody>
</table>
Intelligent packaging react immediately to significantly changing conditions that affect the state of packaged product and they could inform all participant of the supply chain about the current condition of packaged items. They could be applied for direct monitoring of the product quality and dynamic adjustment of their shelf life (DSL attitude).

**Indicators**
- Time-temperature indicators (TTI)
- Microbial growth and freshness indicators
- Integrity (gas) indicators

**Sensors**
- Gas sensors
- Temperature sensors
- Biosensors

**Data carriers**
- Barcodes, NFC communications
- Radio-frequency identification (RFID) systems
- Sensor-enabled RFID tags
Regarding the **final consumer** of food, the information provided by intelligent packaging should be **simple** and **easy to understand**.

The most desirable form of the indicator is a graphically attractive label that changes the appearance and/or colour when food quality changes.

Time-temperature indicators (TTI)

a) Monitor Mark™ (3M)
b) Fresh-Check® (Lifelines Technologies Inc.)
c) CoolVu™ (Freshpoint)
d) Checkpoint® (Vitsab International AB)
e) OnVu™ (Freshpoint)
f) Tempix® (Tempix AB)
g) Timestrip® (Timestrip Plc)
# Time-temperature indicators (TTI)

<table>
<thead>
<tr>
<th>TTI indicator (company, country)</th>
<th>Type of action</th>
<th>Need of activation</th>
<th>Colour change (optical response)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>CheckPoint® types M, L (Vitsab Int. AB, Sweden)</td>
<td>enzymatic</td>
<td>yes</td>
<td>tricolour: green to yellow to red</td>
<td>meat, fish, dairy products</td>
</tr>
<tr>
<td>(e0)® (Cryolog, France)</td>
<td>microbial</td>
<td>no</td>
<td>green to red</td>
<td>cold chain</td>
</tr>
<tr>
<td>FreshCheck® (TEMPTIME Corp. USA)</td>
<td>polymeric</td>
<td>no</td>
<td>colourless to blue</td>
<td>all kind of fresh products</td>
</tr>
<tr>
<td>On Vu™ (Freshpoint, Switzerland)</td>
<td>photochromic</td>
<td>yes</td>
<td>dark blue to colourless</td>
<td>meat, fish, dairy products</td>
</tr>
<tr>
<td>Monitor Mark™ and Freeze Watch (3M Comp. USA)</td>
<td>diffusion-reaction</td>
<td>yes</td>
<td>diffusion of coloured path/material</td>
<td>bakery products, beverage, meat</td>
</tr>
</tbody>
</table>
THE POTENTIAL OF INTELLIGENT PACKAGING IN THE REDUCTION OF FOOD WASTE

Thermochromic packaging elements
Time-temperature indicator => freshness indicator

**CheckPoint L5-8 Smart TTI Seafood Label** – before activation (*white*) and activated (*green*)

**CheckPoint label L5-8 Smart TTI Seafood Label** showing thermal exposure over the safe levels recommended by the FDA
Time-temperature indicator => freshness indicator

Fresh-Check TTI showing when the product is safe and not safe for consumption.

As the Fresh-Check indicator is exposed to heat, it gradually changes color to alert the consumer of optimal freshness.
# Chemical sensors / indicators

<table>
<thead>
<tr>
<th>Target compounds (metabolites)</th>
<th>Food product</th>
<th>Freshness indicator / sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogenic amines</td>
<td>Fish, Seafood, Meat</td>
<td>Colour-changing indicator with pH-sensitive dye / electrochemical sensor for enzyme redox reaction</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Fermented food, Meat</td>
<td>pH sensitive with colorimetric response / electrochemical sensor e.g. with silicon-based polymer recognition layer</td>
</tr>
<tr>
<td>Glucose / Lactic acid</td>
<td>Fermented food, Meat</td>
<td>pH sensitive with colorimetric response / electrochemical sensor for redox reaction</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Meat, Fruits, Vegetables</td>
<td>oxygen sensitive indicator with pH-sensitive dye / optical sensor by fluorescence</td>
</tr>
</tbody>
</table>
## Chemical sensors – integrity indicators

<table>
<thead>
<tr>
<th>Type of indicator</th>
<th>Commercial name</th>
<th>Company (country)</th>
<th>Area of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrity (gas) indicator</td>
<td>Ageless Eye®</td>
<td>Mitsubishi Gas Chemical (Japan)</td>
<td>All packed food products – specially applicable in aseptic and modified atmosphere packaging systems</td>
</tr>
<tr>
<td>Integrity (gas) indicator</td>
<td>Novas®</td>
<td>Insignia Technologies (United Kingdom)</td>
<td></td>
</tr>
</tbody>
</table>
Chemical sensors – integrity indicator

Ageless Eye® gas (oxygen) indicator
Chemical sensors – integrity indicator

Food fresh™ indicator
Chemical sensors – freshness indicators

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<tr>
<td>Freshness indicator</td>
<td>Fresh Tag®</td>
<td>COX Technologies (USA)</td>
<td>Perishable food products, with volatile metabolic products <em>e.g.</em> meat, fish and seafood, dairy products, vegetables and fruits</td>
</tr>
<tr>
<td>Freshness indicator</td>
<td>Raflatac</td>
<td>VTT and UPM Raflatac (Finland)</td>
<td></td>
</tr>
<tr>
<td>Freshness indicator</td>
<td>RipeSense</td>
<td>RipeSense (New Zealand)</td>
<td></td>
</tr>
<tr>
<td>Freshness indicator</td>
<td>SensorQ®</td>
<td>DSM NV and Food Quality Sensor International Inc. (Denmark)</td>
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THE POTENTIAL OF INTELLIGENT PACKAGING IN THE REDUCTION OF FOOD WASTE

Chemical sensors – ripening indicator

ripeSense fruits ripening indicator
Chemical sensors – freshness indicator

Organoleptic assessment scale: (appearance, color, smell, texture):
5 – very good / 4 – good / 3 – sufficient / 2 – insufficient / 1 - bad
Chemical sensors – freshness indicator

<table>
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<tr>
<th>Warunki oznaczenia</th>
<th>Początek oddziaływania z mięsem ryb</th>
<th>12 godzin oddziaływania z mięsem ryb</th>
<th>15 godzin oddziaływania z mięsem ryb</th>
<th>18 godzin oddziaływania z mięsem ryb</th>
<th>24 godzin oddziaływania z mięsem ryb</th>
<th>36 godzin oddziaływania z mięsem ryb</th>
<th>47 godzin oddziaływania z mięsem ryb</th>
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<td>bez HCl</td>
<td>PEG9 PEG34</td>
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<td>0,5 mM HCl</td>
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Chemical sensors – freshness indicator

A sensor that monitors carbon dioxide as indication for the freshness of the dessert golden drop (Nopwinyuwong et al., 2010).
Chemical sensors – freshness indicator

Dual-Optode Label to Monitor Fish Spoilage in Sales Packages
(Magnaghi et al., ACS Food Sci. Technol. 2022, 2, 6, 1030–1038).
Chemical sensors – freshness indicator

Dual-Optode Label to Monitor Fish Spoilage in Sales Packages
(Magnaghi et al., ACS Food Sci. Technol. 2022, 2, 6, 1030–1038)

Fish fillet storage at 4°C for 1-5 days (freshness sensor response)