Potential of Active Packaging Technologies for Food Industry

Gıda Endüstrisinde Aktif Ambalajlama Teknolojilerinin Potansiyeli

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Active Packaging Concept

- Positive interactions between food, food packaging and environment
  - To keep food quality and sensory attributes
  - To increase food safety
  - To extend shelf life
Active Packaging Systems

Active agents for food packaging

- Ethylene scavengers
  - KMnO₄
  - Metal oxides
  - Activated carbon
  - MOFs
  - Titanium dioxide
- Antioxidants
  - Iron
  - Palladium
  - Ascorbic acid
  - Pyrogallol
  - Gallic acid
  - Glucose oxidase
  - Laccase
- CO₂ emitters
  - Essential oils
  - Plant extracts
  - α-Tocopherol
- Antimicrobial
  - Metals
  - Nisin
  - Lactoferrin
  - Essential oils
  - Lysozyme
  - Chitosan
  - Sodium bicarbonate
  - Citric acid
  - Ferrous carbonate
  - Phenolic compounds
  - Lignin
Oxygen Scavengers

Oxygen Scavenging Sachets

Iron Powder Oxidation
Ascorbic Acid Oxidation
Catechol Oxidation
Photosensitive Dye Oxidation
Enzymatic Oxidation
Unsaturated Fatty acids

OXYGEN SCAVENGING TECHNOLOGIES ARE BASED ON:
Oxygen Scavengers

• Iron (Ageless®)
  • Permeable sache including Fe^{+2} oxide as an active ingredient

• Ascorbic acid

• Enzymes
  • Glucose oxidase or alcohol oxidase
Oxygen Scavenging Films

- Oxygen from within the bottle’s headspace is absorbed, reducing oxygen contact with the product.
- Oxygen from outside of the bottle is absorbed, greatly reducing oxygen penetration into the product.
- Carbon Dioxide loss is reduced.
Oxygen Scavengers

Oxygen Scavengers: Amoco

ACTIVE

PASSIVE

● Oxygen from outside the container

● Oxygen from inside the container
Oxygen Scavengers - Application

Shelf-Life After Opening

- Bottle
  - Standard Bag-in-Box: 1 WEEK
  - 4-6 WEEKS
- Scavenger White Wine: 26 WEEKS
- Scavenger Red Wine: 32 WEEKS

Bag in box with oxygen scavenger

Rapak® Active Packaging Scavenger Systems
Oxygen Scavengers-Application

Moon cake packaged in PVDC coated with OPP preserved by $O_2$ scavenging sachet with an indicating $O_2$ sensor (Janjarasskul and Suppakul, 2018).
Oxygen Scavengers - Application

Freshmax - To prevent discoloration and increase the shelf life from 10 days to 180 days.
Application for Sliced Bread

Packaging with BOPP/PVDC Storage at 22°C for 18 days

- MAP (100%N₂) + 100 cc OS 6 days
- MAP (100%N₂) + 300 cc OS 12 days
- Air (21% O₂; 79% N₂)+100 cc OS 3 days
- Air (21% O₂; 79% N₂)+300 cc OS 9 days
- MAP (50% CO₂; 50% N₂) 3 days
- Air atmosphere (21% O₂; 79% N₂) 3 days

Ethylene Scavengers

Ethylene-ripening hormone;

• Accelerates chlorophyll loss ➔ yellowing of green vegetables

• Promotes ripening ➔ increase in senescence and softness

• Stimulates phenyl-propanoid metabolism ➔ browning and bitter taste

• Reduces shelf life of fresh and minimally processed fruits and vegetables
Ethylene Scavengers

- A sachet containing potassium permanganate (KMnO₄)
  - oxidizes or inactivates ethylene
- Use of finely dispersed minerals (zeolite, active carbon, pumice etc.)
  - absorb ethylene
- either in the form of sache or in the packaging film
Ethylene Scavengers

Fruits & Vegetables
STAY FRESH LONGER

21 DAYS
WITH
WITH

21 DAYS
WITH
WITH

9 DAYS
WITH
WITH

14 DAYS
WITH
WITH

ExtraLife

Ethylene removing film bag

Debbie Meyer
GreenBags

PEAKfresh
PRESEVING BAGS
Ethylene Scavengers-Broccoli

**Ethylene Scavengers-Kiwifruit**

<table>
<thead>
<tr>
<th>Color</th>
<th>Day 0</th>
<th>Day 5</th>
<th>Day 10</th>
<th>Day 15</th>
<th>Day 20</th>
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<tbody>
<tr>
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<td>3.33Ab</td>
<td>3.67Ab</td>
<td>3.67Ab</td>
<td>2.67ABb</td>
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<td>5.0Aa</td>
<td>3.17Ab</td>
<td>3.83Ab</td>
<td>3.67Ab</td>
<td>2.17Bc</td>
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<tr>
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<td>5.0Aa</td>
<td>3.33Ab</td>
<td>3.83Ab</td>
<td>4.00Ab</td>
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</table>

<table>
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<tr>
<th>Texture</th>
<th>Day 0</th>
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</tr>
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<tbody>
<tr>
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<td>5.00Aa</td>
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<tr>
<td>M1</td>
<td>5.00Aa</td>
<td>3.00Bbc</td>
<td>3.67Ab</td>
<td>2.83Bbc</td>
<td>2.33ABc</td>
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<tr>
<td>M2</td>
<td>5.00Aa</td>
<td>4.00Abc</td>
<td>3.83Abc</td>
<td>4.17Aab</td>
<td><strong>3.17Ac</strong></td>
</tr>
</tbody>
</table>

K1: unpackaged, M1: PE with no zeolite M2: PE with zeolite
Ethylene Scavengers - Mushroom

- **K1**: unpackaged
- **M1**: PE with no zeolite
- **M2**: PE with zeolite
# Ethylene Scavengers - Banana

## Overall product acceptability

<table>
<thead>
<tr>
<th>Application</th>
<th>Day 0</th>
<th>Day 3</th>
<th>Day 6</th>
<th>Day 9</th>
<th>Day 12</th>
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<tbody>
<tr>
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<td>3,67&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>3,67&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>1,83&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>1,17&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td>K</td>
<td>5,00&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>4,17&lt;sup&gt;Bb&lt;/sup&gt;</td>
<td>3,00&lt;sup&gt;Bb&lt;/sup&gt;</td>
<td>1,17&lt;sup&gt;Ab&lt;/sup&gt;</td>
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<tr>
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<td>1,00&lt;sup&gt;Ba&lt;/sup&gt;</td>
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</table>

**A:** Unpackaged  
**K:** LDPE with no ethylene scavenger  
**S:** LDPE with ethylene scavenging sache  
**P:** LDPE with ethylene absorber (peakfresh)
Antimicrobial Packaging Concept

Two antimicrobial packaging concepts

1) Package/Food system

Food -> Film

2) Package/Headspace

Incorporation of bioactive agents in the packaging matrix: Desorption, and diffusion

Directly bioactive polymer
Antimicrobial Packaging

- Essential oils or natural extracts
- Organic acids
- Metal oxides
  - Nano-silver
  - Nano-calcium oxide
  - Nano-magnezium oxide
  - Nano-zinc oxide
  - Nano-titanium oxide
Encapsulation/Nanoencapsulation

- Encapsulation of bioactive/active compounds before introducing into packaging materials for
  - Controlled release
  - Protecting heat sensitive compounds
Antimicrobial Packaging

Polymer + Nanocapsules: HNTs loaded with essential oils → Antimicrobial polymer/HNTs nanocomposites → Antimicrobial nanocomposite films

Antimicrobial active packaging:
- Fresh meat
- Bakery products
- Dairy products

Polypropylene + Carvacrol → Antimicrobial polypropylene films

Polypropylene + HNTs-carvacrol
Antimicrobial Packaging

Food storage container-PP and PE based material with nanosilver (Anson)
Antimicrobial Packaging

FreshBox w/ nano silver
Antimicrobial Packaging-Sliced Meat Products

- Nano-PP film
  - 1% nanoclay (Dellite® 67G)
- Active-nano-PP film
  - 1% nanoclay and 5% poly-β-pinene
- Commercial multilayer material (control)
  - PP/PA/EVOH/PE (Superfilm, Turkey)
# Antimicrobial Packaging-Sliced Meat Products

<table>
<thead>
<tr>
<th>Application</th>
<th>Shelf-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1-MAP1</td>
<td>60 day</td>
</tr>
<tr>
<td>M1-MAP2</td>
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<tr>
<td>M1-MAP3</td>
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<tr>
<td>M3-MAP2</td>
<td>150 day</td>
</tr>
<tr>
<td>M3-MAP3</td>
<td>150 day</td>
</tr>
</tbody>
</table>

**M1: PPR/nanoclay**

**M2: PPR/nanoclay/PβP**

**M3: PP/PA/EVOH/PE**

**MAP1: (air): 21% \(O_2\)-79% \(N_2\)**

**MAP2: 50% \(CO_2\)-50% \(N_2\)**

**MAP3: vacuum**

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A total of 1% nanoclay containing polypropylene (PP)-nanocomposite and 1% nanoclay plus 5% poly-betapine (PβP) containing PP-active-nanocomposite materials were produced and tested for packaging of sliced salami. The sliced salami was packaged using both monofilms and multilayer film of PP/PA/EVOH/PE under vacuum, modified atmosphere packaging under 50% \(CO_2\) and 50% \(N_2\) and air and stored at 4 °C for 90 days. During storage, headspace gas composition; microbial, physical and chemical analyses; and sensory evaluation were performed. The antimicrobial effect of PβP containing nanomaterial was pronounced under vacuum, and no bacterial growth was observed for 75 days. An 

\[ \text{MDA} = \text{MDA before processing} - \text{MDA after processing} \]

value decreased notably in all applications during storage and preserved best by the multilayered material under vacuum and high \(CO_2\). Thiobarbituric acid reactive substances (TBARS) were 0.63 mg MDA/kg after the processing and gradually increased at all applications during harvested storage. TBARS values of all vacuum and modified atmosphere packaging films had higher values than vacuum packaging.
Future Concepts

• Intelligent packaging integrated with active packaging concept (sensors) to determine freshness, food spoilage or gas level inside the package

• Multifunctional, interactive packaging and nanotechnology based products

• Smart house equipment compatible with food packages of ready to eat/consume
THANK YOU VERY MUCH FOR YOUR ATTENTION!

Active Packaging Applications for Food

Selcuk Yildirim, Bettina Röcker, Marit Kvalaug Pettersen, Julie Nilsen Nygaard, Zehra Ayhan, Ramuute Rutkaitie, Tanja Radusine, Pasiya Suminska, Segouye Marcos, and Venetia Coma

Abstract: The traditional role of food packaging is continuously evolving in response to changing market needs. Current drivers such as consumers' demand for safer, "healthier," and higher-quality foods, ideally with a long shelf-life, the demand for convenient and transparent packaging, and the preference for more sustainable packaging materials, have led to the development of new packaging technologies, such as active packaging (AP). As defined in the European regulation (EC) No. 450/2009, AP systems are designed to "deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food." Active packaging materials are thereby "intended to extend the shelf-life or to maintain or improve the quality of packaged food." Although extensive research on AP technologies is being undertaken, many of these technologies have yet to be implemented successfully in commercial food packaging systems. Broad communication of their benefits in food product applications will facilitate the successful development and market introduction of new packaging technologies. In this review, an overview of AP technologies, such as antimicrobial, antiautocatalytic, carbon dioxide-releasing systems, and systems absorbing oxygen, moisture, or ethylene, is provided, and, in particular, scientific publications illustrating the benefits of such technologies for specific food products are reviewed. Furthermore, the challenges in applying such AP technologies to food systems and the anticipated direction of future developments are discussed. This review will provide food and packaging scientists with a thorough understanding of the benefits of AP technologies when applied to specific foods and hence can assist in accelerating commercial adoption.

Keywords: active packaging, antimicrobial packaging, antioxidant release, ethylene absorber, oxygen scavenger

Introduction

Packaging plays a critical role in the food supply chain. The primary function of packaging is to serve as a consumer for the food, enabling efficient transport within the supply chain, preventing any physical damage, and protecting against manipulation and theft. Packaging also meets the fundamental need to maintain food quality and safety from production to final consumption by preventing any unwanted chemical and biological changes. Hence, the packaging acts as a barrier to protect the food from environmental influences, such as oxygen, moisture, light, dust, pests, odors, and both chemical and microbiological contamination. (Codex and others 2003; Yildirim 2011; Arvanitoyannis and others 2012; Penina de Abreu and others 2012). The protective role of the packaging is primarily passive, acting as a barrier between the food, the atmosphere surrounding the food, and the external environment. However, there are some exceptions, such as fresh produce, for which highly gas permeable or perforated packaging materials are used to allow gas exchange through the packaging film and polk (1997; 14 hours and others 2015). Such packaging systems, however, are limited in their ability to further extend the shelf-life of the packaged food. Over recent decades, consumer concerns about the safety and additive content of food has received much attention. There is an increasing trend toward natural high-quality foods, which are uncompromised or minimally processed. In many cases, this has led to the development of new packaging technologies, such as modified atmosphere packaging (MAP) (Elhassan and Benmouna 2002; Rodriguez-Aguilera and Ollero 2009; Sundays-Diata, Chirac 2014; Zhan and others 2014), active packaging (AP) (Singh and others 2011; Yildirim 2011; Arvanitoyannis and Oikonomou 2012; Penina de Abreu and others 2012; Dobroska and Ciepiela 2014; Penina and Marcos 2014; Kaused and others 2015; Breckenkorn and Abbas 2019; Smart and Intelligent packaging (SIP) (Kerry and Butler 2008; Lee and Lim 2014; Stadler and Maurus 2014; Ippi and others 2015; Breckenkorn and Abbas 2016) and the application of nanomaterials (Onsen and others 2010; Kwon and others 2012)