Ecodesign In Food Packaging

UNIT 10: Active and Intelligent Packaging

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After acquiring this unit, the student will be able to:

- -Know the main types of active and intelligent food packaging;
- -Know the principles underlying technologies for producing active and intelligent food packaging;
- -Know the active and intelligent food packaging applications

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10.1 Definitions

Regulation (EC) no. 450/2009 includes the following definitions and requirements:

"Active materials and articles" means materials and articles intended to extend the shelf life or to maintain or improve the condition of packaged food; they are designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food;

--"release of active materials and objects " are those active materials and articles designed to deliberately incorporate components that would release substances into or onto the packaged food or the environment surrounding the food;

--"released active substances" are those substances intended to be released into the interior or onto the packaged food or the environment surrounding the food and fulfilling a purpose in the food.

-"component" is an individual substance or a combination of individual substances which cause the active substance and / or the smart feature of a material or of an article, including the products of those substances; it does not include the passive parts such as the material to which they are added or incorporated;

The active packaging is a type of food packaging with an additional function, besides the fact that it provides a protective barrier against external influence. The active packaging is intended to influence the packaged food. The packaging absorbs the chemical substances related to the food derived from food or the environment surrounding the food; or releases substances into food or the environment surrounding the food such as preservatives, antioxidants, flavourings etc.

"Intelligent materials and articles" means materials and articles which monitor the condition of the packaged food or the environment surrounding the food.

Intelligent packaging provides the user with information about the status of the food provided to be reliable and accurate. The component base can be positioned on the outer surface of the pack and can be separated from the food by a functional barrier.

10.2 Active materials and articles

Following the definition of active materials and articles, we can group the examples as follows:

A) The absorption[1]/ cleaning systems:

Moisture absorption: Cushions used, for example, to absorb the drops from the meat, poultry and fish in the primary packaging. They can, for example, be a plastic laminated mesh as adhesive and pads containing only the polymeric fibers or granular

[1] Physical phenomenon by which a liquid or solid body incorporates, by diffusion from the outside, a certain substance
https://dexonline.ro/definitie/absorb%C8%9Bie

polyacrylates or in combination with natural cellulose all contributing to the absorbing function of this cushions.

Materials and articles that work exclusively on the basis of natural components, such as pads composed of 100% cellulose, do not fall under the definition of active materials and articles because they are not designed to deliberately incorporate components that would release or absorb substances. Other examples of absorbents which enter and which do not fall under the definition of active materials and articles are presented in ***Annex 1.***

Fig. 1: Absorbent cushions and envelopes and an ethylene absorbent bag
A) Moisture absorbers, B) Oxygen absorbers, C) Ethylene absorbers

Oxygen absorbers are used in the packaging of pasta, milk powder, biscuits etc. These absorbers are usually in the form of envelopes. They remove or capture the residual oxygen inside the packaging (from the environment of the food product or from the food itself) to reduce exposure to oxygen. Exposure to oxygen can lead to increased microbiological food, chemical changes in food, etc. An oxygen absorber is intended to reduce these effects thereby prolonging the shelf life of food products. The most commonly used O2 absorbers are iron powder and ascorbic acid. The most commonly used is iron powder which has a large surface area reaction. Absorbers can reduce the concentration of oxygen in the free space of the packaging to 0.01%. You can use different amounts of absorbing oxygen from 20 to 2000 ml of oxygen. Modern cleaning pads use a mixture of iron powder and sodium chloride for O2. Often, activated carbon is also included as it absorbed[2] into the pores of his other gases and many organic molecules, while still retaining the products and removing odors. The factors that lead to choosing the type and size of the canister include the size, weight and shape of the product; water activity in the product; the amount of oxygen dissolved in the product; the period of validity required for the product; the permeability to oxygen of the packaging material; the initial level of oxygen in the headspace of the package. Various applications are: ground meat products, cooked, preserved, fish treated, bakery products, dried products, milk, dried eggs, spices, herbs and confectionary products.

Ethylene absorbers can be used as envelopes or incorporated in a polymer film. An application example is a plastic bag with an incorporated ethylene absorbent.

[2] **Adsorbtion** in physics represents the phenomenon of retaining the molecules of a fluid substance (called adsorbate) on the surface of a liquid or solid body (adsorbent). Because of its small thickness, this surface (called superficial layer) can be considered homogeneous and having specific properties different from those of the separated phases. https://ro.wikipedia.org/wiki/Adsorb%C8%9Bie

Ethylene, a natural growth hormone of plants, is a key to the ripening process of fruits and vegetables, being released during respiration and then leading the process of maturation. The active component of the polymer is designed to prevent excess ethylene, to extend the shelf life of the product packed.

Most of the ethylene absorbents are based on potassium permanganate. Other ethylene absorbers are activated carbon, bentonite and aluminosilicates (e.g., zeolites).

Carbon dioxide absorbers

Carbon dioxide absorptions can be of two types:
a) containing the absorbent physically (zeolite);
b) containing the absorbing chemically (calcium hydroxide).

Moisture absorbers

A part of the environmental vapors of the package pass through it due to its permeability and condenses in the packing due to the change in temperature. Also, drops of water appear contained in the food. Also, water is produced during the decomposition of fats and carbohydrates. The accumulated water can cause growth of micro-organisms leading to food degradation. Excessive water can be removed by the use of a food wrapping impermeable to water vapor. Common absorption systems include a super absorbent polymer placed between two layers of polymer microporous or nonwoven. Use the salts of the poly acrylate, carboxyl methyl cellulose (carboxy methyl cellulose - CMC), starch-containing copolymers.

Removing odors

Odors and unwanted flavors are removed through the removal of amines, aldehydes and fatty acids produced during the oxidation of primary and secondary fatty acids. Bitter compounds (limonin) are also eliminated from the juices of the fruit. Some unpleasant odors can be perceived by consumers at the opening of the pack, even when the food can be consumed safely. The processing of plastics, such as casting, extrusion, can cause unpleasant odors. Antioxidants can also be used to reduce unpleasant odors. From a commercial point of view, very few packaging techniques have been used to selectively eliminate unwanted flavors and compounds with undesirable taste, but there are many potential opportunities. An example of such an opportunity is to combat the bitter taste of pasteurized orange juices. Some orange varieties are particularly prone to bitter flavors caused by limonin, a chemical compound that is released into the juice after pressing and pasteurizing the oranges. A possible active packaging solution would be to incorporate limonine adsorbents (e.g., cellulose triacetate or acetylated paper) into orange[3] juice packaging materials.

B) Food substance delivery systems:

Applications are packaging that contain substances that are emitted to the food such as preservatives, antioxidants, flavourings, enzymes. These released active substances are intentionally added into or onto the packaged food to fulfill a task given

[3] RICHARD COLES, DEREK MCDOWELL, MARK J. KIRWAN FOOD PACKAGING TECHNOLOGY, Blackwell Publishing Ltd, 2003

in the food or in the environment surrounding the food and to maintain or extend the shelf life of the food packaged.

Antimicrobial agents

Meat and meat products are more susceptible to damage microbial. The main purpose is reducing, inhibiting or retarding the growth of microorganisms. Antimicrobial agent increases the phase delay and decreases the phase of the growth curve of microbial development and, ultimately, reduces the growth of microorganisms. The ethanol emitters can be used to enhance the storage life of the bread, dried fish products and semi-dried and for the preservation of the bread [4]. Other antimicrobial agents are indicated in annex 1, ***table A1-1.***

C) Systems with inserted or applied substances on the wall of the pack*:*

Applications are packaging that contain an additive or an enzyme which is applied on the surface in contact with food and has a technological effect on the food. These materials incorporate one or more active components that influence deliberately the condition of the food without migration intent. This category of packaging is thus similar to the previous one with the difference that the active substance is not released in food, but remains applied or inserted on the surface of the pack; any migration into food is not intentional.

Active packaging	**Aplications**
Oxygen absorbers	Practically all classes of foods
Emitters of CO2	Virtually all of the foods affected by mold
Water vapor absorbers	Dry food and sensitive to motion
Ethylene absorbers	Horticultural products
Emitters of ethanol	Cooked dishes (where permitted)

A detailed table of active systems used in food packaging is given in ***Annex 1***.

10.3 Smart materials and articles

Smart Packaging can be grouped into:

A) Product quality indicators - the Indicators time-temperature (Time Temperature Indicators - TTI), Gas indicators, Fresh indicators etc.

B) Product protection – Package breaking, stealing, etc.

C) Increase the usefulness - during preparation and cooking of food.

In addition, each indicator used in the packaging should be characterized by the following features:

- low price;
- the ability to read without having to use a device;
- non-toxic;

[4] Simran Kaur, 2 Divya Puri, Active and intelligent packaging: A boon to food packaging, International Journal of Food Science and Nutrition
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- stability;
- sensitivity;
- the reaction must be irreversible;
- easily inserted in the package.

Time-temperature indicators

- Are meant to provide information as to whether a temperature threshold has been exceeded in time and / or until the minimum time estimated that a product spent above a temperature threshold (temperature histories in time) e.g. from the moment in which the foods are packaged at the point of consumption. The indication is often a visual signal. A positive visual signal could indicate that a product is no longer fresh or is not suitable to be eaten. The provided information must be reliable and accurate and to not mislead the consumer.

Indicators trading - TTI:

– LifeLinesFresh-Check

- Based on the polymerization reaction

– 3M Monitor Mark

- Based on the diffusion of the dye

– Vitsab®TTI (Cox Technologies)

- Based on color change of the lipase[5]

Fig. 2: Examples of indicators TTI

The oxygen indicator

This indicator provides information about the leaks. The indicator is used for food packaging controlled or with modified atmosphere. An typical oxygen indicator consists of a redox dye (ex. blue methyl), a alkaline compound (ex.sodium hydroxide) and a compound reducing agent (ex. reducing sugars). Other indicators of oxygen-based enzyme oxidative. In addition, a solvent is added (water or an alcohol) and a bulking agent (e.g., silica gel, polymers, cellulose, zeolites).The indicator may be a label, a printed layer, a tablet, or it can also be laminated in the polymer (film).[6]

[5] Enzyme of digestive juices that moisturizes fats, sputtering them into glycerol and fatty acids

[6] Semih Otles, Buket Yalcin, INTELLIGENT FOOD PACKAGING, Ege University, Bornova-Izmir, Turkey, ISSN 1734-459X, 2008, Vol. 4

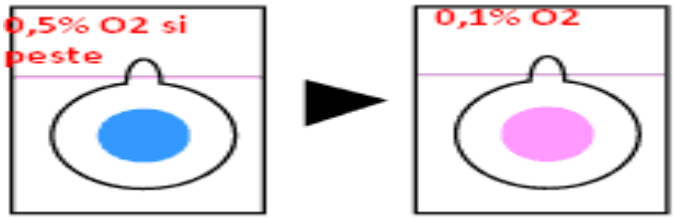

Fig.3: Indicator of O2. Present blue O2, limited red O2

In Annex 2, Table A2-1 some indicators used in the inside or the outside of food packaging are presented. There are indications regarding the type of indicator, the operating principle, the information obtained with them and the current applications of the described indicators.

10.4 The functional barrier

Regulation (EC) no. 450/2009 gives the following definition:

• ***'Functional barrier'*** means a barrier consisting of one or more layers of material that comes into contact with food, which makes the material or finished article to be in accordance with article 3[7] of Regulation (EC) no. 1935/2004 and with this regulation.

This barrier is a layer of the material or articles which come into contact with food, preventing the migration of substances from the face of the barrier in food.

The maximum level of migration tolerated is 0.01 mg of substance / kg food for a substance. This migration limit is applicable to a group of substances, in particular from the point of view of structural and toxicological interdependent, in particular if they are isomers of the same substance or substances of the same functional group; it also includes the transfer possible outside of the pack.

If it is demonstrated that the packaging material or a layer acts as a functional barrier to migration[8] , a non-authorised substances in the layer (layers) from behind the barrier can be used (not in contact with food) provided it does not fall within one of the following categories:

• Substances that are mutagenic, carcinogenic or toxic to reproduction.

• New technologies that induce chemicals that have chemical and physical properties that differs significantly from the constituent parts of the packaging, eg nanoparticles, should be assessed on a case-by-case basis for their risk until more

[7] Article 3 - General requirements:
1. Materials and articles, including active and intelligent materials and articles, shall be manufactured in accordance with good manufacturing practice in such a way that, under normal or foreseeable conditions of use, they do not transfer to the food products the substances which are incorporated in such quantities could: (a) endanger human health; or (b) cause an unacceptable change in the composition of the food; or (c) alter their organoleptic characteristics.
2. The labeling, advertising and presentation of a material or article shall not mislead the consumer.

[8] This must be demonstrated in the declaration of conformity and in the supporting documentation ((EC) No. 450/2009, Article 13 and Annex 2].

information is known about this new technology. Therefore, they are not covered by the functional barrier concept.

So far, they have been found in three types of situations:

- **for recycled plastics**: recycled plastic materials can be contaminated by different chemical products in the consumer environment; to prevent such contaminants to reach the food, a functional barrier between the recycled plastic and food is intercalated;
- **for substances not approved by regulation**: according to a draft EU regulation, the industry will be authorized to use substances which are not approved by the authorities responsible for public health, (i) if these substances are not carcinogenic, and (ii) if they are separated from the food by a functional barrier, which ensures that are not detectable in food. Such substances are called in the regulation, "substances of the functional barrier;
- **for active packaging**: in the area of active packaging, the functional barriers can prevent migration of active substances or of constituents of the active substance.

Unlike glass or metals, which are absolute barriers over a minimum thickness, it is not possible to indicate general rules for plastic materials. The efficiency depends on the history of the food or of the polymer, as well as the geometric properties of the packaging, mainly their thickness. Some general information can be given:

- it is unlikely that the polyolefines and EVA to be able to act as a functional barrier, whatever the thickness of the layers may be;
- other polymers, PET, EVOH, PVC, PVDC, PAN can act as a functional barrier if the barrier layer is thick enough.

To decide on the minimum thickness you can use a software which takes into account the entire history of the material for food contact. The software [MULTITEMP and MULTIWISE] (INRA) is able to successively describe:

- diffusion into the barrier during processing (taking into account a rate of cooling);
- diffusion into the barrier during storage of the blank packaging;
- migration during the filling at hot;
- migrating during storage of the food (taking into account the effects of inflation).

The efficiency of the layers of polymer may vary very much, if the penetration takes place in a few hours in PE, in PET, for the same thickness of foil, it can even be achieved in over 100 years (Gross, 2014). Many manufacturers have made, for example, cardboards having barrier layers either as a layer applied by the substance or with laminated sheets. The materials used for this range from acrylates to combinations of EVOH with polyamides and polyesters. Barriers raise many problems with recyclability, cardboard adherence, packaging performance. An example of such material is Foodboard, marketed by Mayr-Melnhof, a large Austrian company producing cardboard and cardboard packaging.

It has been marketed after 5 years of research by a team of 20 specialists, for which over 14,000 tests and two million cartons have been made. It comes with an innovative, ecological and biodegradable barrier. Due to this protective layer, packaged foods are

protected from substances such as mineral oils, phthalates, BPA and other substances that may appear through the packaging (Mayr-Melnhof Karton, 2015).[9]

[9] GRIGORESCU (AMZĂR) Mihaela Student Scientific Session, 15-16 May 2015, Scientific coordinator: Şl. Nicoleta Pascu, PhD, FOOD SAFETY FOR CARTON PACKAGING

Table A1-1 Active Packaging System [10]

Active Packaging System	Active elements	Food applications
Oxygen absorbers	Iron- metallic catalyst /acid, metal (e.g., platinum), ascorbate/metallic salts, enzymes and nylon	Bread, cakes, cooked rice, biscuits, pizza,pasta, cheese, treated meats and fish, coffee, snack foods, dried foods and beverages
Carbon dioxide emitters	Iron oxide/calcium hydroxide, ferrous carbonate/metallic halide, calcium oxide/ activated charcoal and ascorbate/sodium bicarbonate	Coffee, fresh meats and fish, nuts and other snack foods and sponge cakes
Ethylene absorbers	Potassium permanganate, activated carbon and activated clays/zeolites	Fruits and vegetables
Antimicrobial (AM) packaging	Organic acids, silver zeolite, spice and herb extracts, BHA/BHT antioxidants, vitamin E antioxidant, chlorine dioxide and sulphur dioxide	Cereals, meats, fish, bread, cheese, snackfoods, fruits and vegetables
Ethanol emitters	Encapsulated ethanol	Pizza crusts, cakes, bread, biscuits, fish and bakery products
Moisture absorbers	Polyethylene, activated clays and minerals and silica gel	Fish, meats, poultry, snack foods, cereals,dried foods, sandwiches, fruits and vegetables
Flavor/odor adsorbers	Cellulose triacetate, acetylated paper, citric acid, ferrous salt/ascorbate (vitamin C or ascorbic acid) and activated carbon/clays/zeolites	Fruit juices, fried snack foods, fish, cereals, poultry, dairy products and fruits
Self-heating and self-cooling	Quicklime/water, ammonium nitrate/water and calcium chloride/ water	Ready meals and beverages
Changing of gas permeability	Side chain crystallizable polymers	Fruits and vegetables
	BHA and BHT are antioxidants. Oxygen reacts preferentially with BHA or BHT rather than with fats or oils, thereby protecting them from spoilage.	

[10] Simran Kaur, 2 Divya Puri, Active and intelligent packaging: A boon to food packaging, International Journal of Food Science and NutritionISSN: 2455-4898, July 2017

Annex 2: Intelligent packaging systems

a) Indicators

- Time-temperature indicators - TTI
- Oxygen indicator
- Carbon dioxide indicator
- Color indicator
- Microbial growth indicator
- Packaging breaking indicator
- Freshness indicator (microbial damage or pathogens)
- Leak indicator
- Devices for gas detection

b) Traceability devices

- Chip / labels for radio frequency identification - RFID

c) Sensors

- Intelligent sensors
- Bio-sensors
- Identification gas sensors
- Oxygen sensors based on fluorescence

Tabel A2.1 Several indicators used in the inside or outside of food packaging [11]

Indicator	Principle/ Reagents	Obtained information	Applications
Time- temperature indicators (External)	Mechanical Chemical Enzymatic	Storage conditions	Cold and frozen foods
Oxygen- Indicators (Internal)	Redox indicators (reduction-oxidation reaction), colours indicators, pH indicators (colour indicators with enzymes)	Leakage from packaging due to storage conditions	Foods stored in packages with reduced oxygen concentration
Carbon dioxide- Indicators (Internal)	Chemical	Leakage from packaging due to storage conditions	Modified or controlled atmosphere food packaging
Microbial growth indicators (Internal/ External)	Color indicators for pH. All colorants that react with certain metabolites (volatiles or non-volatiles)	Spoilage (Food microbial quality)	Perishable foods such as meat, fish and poultry
Pathogen indicators (Internal)	Various chemical and immunochemical methods reacting with toxins	Pathogenic specific bacteria such as Escherichia coli 0157	Perishable foods such as meat, fish and poultry
Intermediates and metabolism products			
IMMUNOCHEMISRTY s. f. Branch of biochemistry dealing with the study of the chemical nature of immunity for the preparation of purified vaccines and sera. – From fr. **immunochimie.**			

[11] Simran Kaur, 2 Divya Puri, Active and intelligent packaging: A boon to food packaging, International Journal of Food Science and Nutrition ISSN: 2455-4898, July 2017