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A review on active food packing as innovation strategies for the future

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Abstract. Due to the dynamic life, consumers are constantly seeking to increase the shelf life of packaged food products, encouraging scientists in various fields to develop innovative packaging that meets the demands of consumers and at the same time producers. The purpose of this paper is to review the latest trends in the development of active packaging (AP) for foods. Given the specific properties of each type of food as well as the storage and distribution conditions, the choice of packaging material with accompanying elements requires a careful approach to each type of food. The knowledge of packaging materials, food properties, physics, and engineering is applicable to food packaging and has evolved to provide solutions to various food hazards along the packaging chain. Active packaging is one of the most dynamic and innovative technologies that aim to extend the shelf life of food or to improve safety while maintaining food quality. Its activity is based on the internal properties of the polymer or the specific properties of additives included in packaging systems which can be successfully used in packaging to increase the shelf life of processed foods but only under certain specific conditions. Active packaging is categorized into absorption or release systems, like oxygen, ethylene, odorless, fragrance, flavored, antimicrobials, and moisture absorbents, which can react with time depending on the conditions of the food inside the packaging. Released substances must be substances authorized in the context of food legislation and may be used only in the authorized limits.

Keywords: Food, innovative package, active package, food contact materials

1. Introduction

The shelf life of food is the period during which the food retains acceptable characteristics of flavor, aroma, texture, color, nutritional value, and safety under defined environmental conditions (Dong Sun Lee, et al. 2008). Food packaging is one of the methods of food storage. Food packaging technology is of major importance to any food industry as it plays a key role in the development of any industry and its competitive advantage. Due to the dynamic life, consumers are constantly seeking to increase the shelf life of packaged food products, encouraging scientists in various fields to develop innovative packaging that meets the demands of consumers and at the same time producers. The packaging has an interdisciplinary character. It includes the activities of some professional and creative scientific activities such as graphic design, applied arts, food packaging, food technology, graphic technology, information technology, psychology, marketing, or material technology (Wyrwa, et al. 2017). This is what makes packaging respond with amazing innovations to all of its accelerated styles of modern society (Coles et al., 2003). New technologies of food packaging and packaging materials, such as active and intelligent packaging, nanotechnologies, biopolymers, biosensors, and less energetic processes are possible for innovative products (Mahalik and Nambiar, 2010), but must first be tested and evaluated (Pocas and Hogg, 2007). As innovative food packages are considered Modified Atmosphere Packaging (MAP), Active packaging (AP), Intelligent packaging (IP), edible/biodegradable packaging (BP), nanocomposites, and other options (Kapetanakou AE, Skandamis PN (2016).

Modified atmosphere packaging (MAP) as a packaging system that involves changing the gaseous atmosphere surrounding a food product inside a pack, and employing packaging materials and formats with an appropriate level of gas barrier can maintain the changed atmosphere at an acceptable level for the preservation of the food (FMCG, 2013). Also, MAP can be defined as the enclosure of food in a package in which the atmosphere inside the package is modified or altered to provide an optimum atmosphere for increasing shelf life and maintaining food quality. According to the food type in the packaging, oxygen is eliminated and the packaging is filled with CO_2 with N_2 gases in different concentrations.

An intelligent package is defined as a package that contain an external or internal indicator that monitored the conditions of packaged foods and give information to users about the quality of the food during storage and transport. Also, intelligent packaging can be defined as "packaging that contains an external or internal indicator to provide information about aspects of the history of the package and/or the quality of the food" (Robertson, 2006). Intelligent systems can be classified into sensors, indicators, and radiofrequency identification (RFID) systems.

In this paper, we will focus on reviewing the latest trends in the development of active packaging (APP) for foods.

Active packaging refers to the incorporation of additives into packaging systems to maintain or extend the shelf-life and quality of fresh foods and food products. It is used to protect the quality of food during its shelf life, increase food safety, extend the shelf life of the product, reduce food losses, reduce the use of food additives, as a marketing tool, and develop new products. Other systems of active packaging can be self-heating or self-cooling systems. Packaging components may actively control the heating or cooling speed of some liquid foods (Dong Sun Lee, et al. 2008 /460).

2. Materials and Methods

The method used in this paper was based on release and absorption systems from food packages and the short survey about consumer awareness (only students in the field of technology) about innovative packages was used. The survey was distributed to 198 students as consumers of food packaging in Prishtina, capital city of Kosovo.packaging in Prishtina.

3. Overview of Active Packaging Technologies and Concepts

Active packaging is an innovative concept that can be defined as a mode of packaging in which the package, the product, and the environment interact to prolong shelf life or enhance safety or sensory properties while maintaining the quality of the product (Ishrat Majid et al, and Han JH, et.al. 2005). Active packaging involves physical, chemical, or biological action to alter the interactions between the package, the product, and the package headspace to achieve certain desired outcomes.

Active packaging systems (Fig 1.) are categorized into **absorption or release systems**, like **oxygen, ethylene, odorless, fragrance, flavored, antimicrobials, and moisture absorbents**, which can react with time depending on the conditions of the food inside the packaging (Fig, 2)

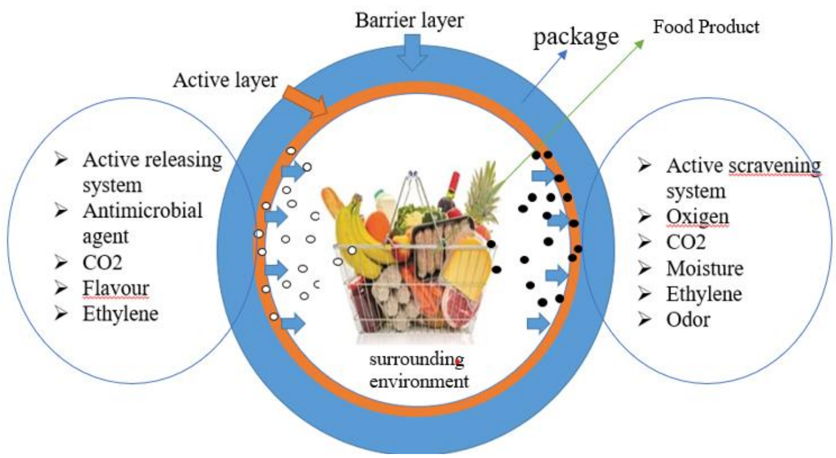

Fig.1 Active package systems

3.1. Absorbing system: is a group of technologies that use sachets ore packaging films to remove undesired gases and substances (e.g. oxygen, carbon dioxide, moisture, ethylene, taints) from the package so that a favorable internal package environment and food condition are achieved.

3.2. Releasing system is a group of technologies that are used to add or emit desired or active compounds (e.g. carbon dioxide, ethanol, antimicrobials, antioxidants, enzymes, flavors, nutraceuticals) to protect and enhance food quality.

3.3 Other systems of active packaging: self-heating, self-cooling, microwave susceptor, selectively permeable film.

3.1.1 Oxygen absorbers: The presence of oxygen in food is often causes undesirable and deteriorated reactions to food (lipid oxidation, change in flavor and color of food, development of microbes, yeasts, and mold). The oxygen-absorbing system is based on oxygen-absorbing sachets, self-adhesive labels, and adhesive devices which are placed on the package or attached to the proper packaging placement. The most successful oxygen absorbers in sachets are based on Fe, ascorbic and metallic salts. The basic oxidation reaction used by iron to absorb oxygen can be described as:

$$4Fe + 3\ O_2 + 6\ H_20\ = 4\ Fe\ (OH)_2$$

3.1.2. Ethylene absorbers: Ethylene produced through respiration from fruits and vegetables can accelerate their aging and decay. Each package of fresh produce contains a certain level of ethylene in the packaging space. which affects their deterioration by reducing their shelf life. The presence of gaseous ethylene in the packaging of products is mainly harmful. So, the removal of ethylene is desirable for keeping the freshness of fresh fruit and vegetables. The ethylen-absorbing system is based on potassium permanganate, silica gel, activated carbon. The potassium permanganate agent react to remove ethylene according to the reaction:

$$3\ C_2\mathbf{H_4} + 12\ KMnO_4 = 12\ MnO_2 + 12\ KOH + 6\ CO_2$$

The potassium permanganate should not be in contact with the surface of food due to its toxicity.

3.1.3. Misture absorbers: The main use of the moisture absorber is to maintain the low water activity of packaged dry foods, the physical qualities of which are lost during the absorption of moisture on their surface. The moisture-absorbing system is based on desiccants of silica gel, calcium chloride, and calcium oxide. Calcium oxide reacts to remove water visibly like:

$$CaO + H_20\ = Ca\ (OH)_2$$

3.1.4. Carbon dioxide absorber: This compound is produced by the degradation reaction, microbial growth, and respiration. e.x. The high amount of CO_2 produced in coffee roasting is released through the packed coffee storage. Fresh produce consumes oxygen and produces CO2 by aerobic respiration. Excessive CO_2 accumulation in packaging can cause physiological damage to fresh fruits and vegetables, so the controlled removal of CO2 from food package headspace is desired for these kinds of package situations. The carbon dioxide-absorbing system is based on calcium hydroxide, active carbon, and zeolite etc. The calcium hydroxide reacts to remove CO_2 according to the reaction:

$$Ca\,(OH)_2 + CO_2 = CaCO_3 + H_2O$$

3.2.1. Carbon dioxide releaser: There are some cases of package collaps due to the reduction of the volume or the reduction of the atmospheric pressure of the gas spaces inside the packaging. The emission of CO_2 responding to O_2 gas absorbed can be described according to the reaction:

$$4\ FeCO_3 + 6\ H20 + O_2 \rightarrow 4\ Fe\ (OH)3 + 4\ CO_2$$

CO_2 emitters actively produce and release this gas within the package to inhibit spoilage and control harmful microorganisms, preserving food quality. CO_2 emitters are often found in products like coffee, snack foods, nuts, bakery items, dried and fresh meats, and fish.

3.2.2. Antioxidant releasers: Although an oxygen scavenger in packaging prevents or delays the oxidative deterioration of packaged food, antioxidants may be incorporated into or worn in food packaging materials to be released into the main space or food for more effective control of oxidative changes. The antioxidant releasers are based on sintetic or natural antioxid t such as butylathydroxytolueneene (BHT) and α – tocopherol incorporated in polyethylene (PE) polymer and polypropylene (PP) package. Antioxidant can be incorporated into package material together with antimicrobial angent to preserve perishable foods.

3.2.3. Antimicrobial Packaging Systems: is a system that can kill or inhibit the growth of microorganisms and thus extend the shelf life of perishable products and enhance the safety of packaged products. The controlled release of antimicrobial agents from the food packaging material to the food surface is considered to be able to inhibit or reduce the growth and decay of microbes by using the minimum amount of antimicrobial agent in the food consumed. The antimicrobial packaging system is based on the use of antimicrobial sachets placed inside packaging, packaging films, and edible coatings incorporating active antimicrobial substances, and MAP, alone or in combination with another antimicrobial method. The antimicrobial compound proposed and tested for incorporation if packaging materials include ethanol, silver ion, organic acids such as sorbates, propionate, and benzoate, bacteriocins such as niacin and pediocin, chitosan and enzymes such as lysozyme. As antimicrobial agents are used ethanol emitter

3.3.1. Sulphur dioxide: Mold growing on soft fruits such as strawberries, peaches, and grapes can easily penetrate the fruit's outer skin layer, causing damage inside the fruit. Sulfur dioxide is mainly used to control the development of mold in some fruits. For example, to avoid, mold growing the grapes need to be stored in the refrigerator in combination with smoking using low levels of sulfur dioxide (Shanky Bhat, 2013).

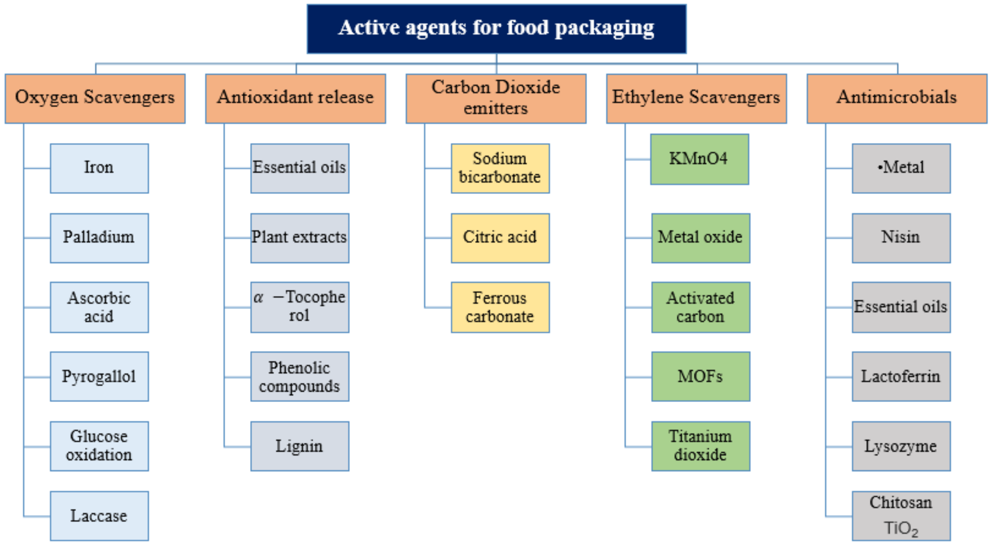

Fig. 2 Active agents which are used for active food package

In the Tab 1. are described the systems of active packaging, the active agents thare are used for each system, the application of them and they beneficial effect in some foods.

Tab. 1 Selected systems of the active package and their effects on some foods

SELECTED SYSTEMS OF ACTIVE PACKAGE AND THEIR EFFECTS ON SOME FOODS				
	Active System	Mecanisms/agents	Applications	Potential benefits
1	Oxygen scavengers	1. Iron-based 2. Metal/acid 3. Metal (e.g., platinum) catalyst 4. Ascorbate/metallic salts 5. Enzyme-based	(sliced) cooked meat products, bread, cakes, cooked rice, biscuits, pizza, pasta, cheese, cured meats, cured fish, coffee, snack foods, dried foods and beverages	Prevention or reduction of aerobic microbial growth Prevention or reduction of oxidative quality detoration Prevention of discoloration, browing, mold growth, rancidity of food and retention of vit. C,
2	Carbon dioxide scavengers/ emitters	1. Iron oxide/calcium hydroxide 2. Ferrous carbonate/metal halide 3. Calcium oxide/activated charcoal 4. Ascorbate/sodium Bicarbonate	Coffee, fresh meats, fresh fish, nuts, other snack food products and sponge cakes	Extension of microbiological shelf life, reduction in head space volume of modified atmosphere packaging.
3	Ethylene scavengers	1. Potassium permanganate 2. Activated carbon 3.Activated clays/zeolites	Fruit, vegetables, and other horticultural products (climacteric fruit and vegetables)	Reduction in ripening and senescence, there by enhancing the quality and prolonging shelf–life.

4	Preservative releasers	1. Organic acids 2. Silver zeolite 3. Spice and herb extracts 4. BHA/BHT antioxidants 5. Vitamin E antioxidant 6. Volatile chlorine dioxide/sulphur dioxide	Cereals, meats, fish, bread, cheese, snack foods, fruit and vegetables	Use for antimicrobial and antioxidant packaging films which have preservative properties for extending the shelf life of a wide range of food products.
5	Ethanol emitters	1. Alcohol spray 2. Encapsulated ethanol	Pizza crusts, cakes, bread, biscuits, fish and bakery products Cooked food (where it is allowed)	Ethanol is an antimicrobial agent particularly effective against mould but can also inhibit the growth of yeasts and bacteria.
6	Moisture absorbers	1. PVA blanket 2. Activated clays and minerals 3. Silica gel	Fish, meats, poultry, snack foods, cereals, dried foods, sandwiches, fruit, and vegetables	Moisture drip absorber pads, sheets, and blankets or Microporous sachets Inhibiting microbial growth and moisture-related degradation of texture and flavor.
7	Flavour/odour adsorbers	1. Cellulose triacetate 2. Acetylated paper 3. Citric acid 4. Ferrous salt/ascorbate 5. Activated carbon/clays/Zeolites	Fruit juices, fried snack foods, fish, cereals, poultry, dairy products, and fruit	Debittering of pasteurized orange juices. BMH™ powder can be incorporated into the packaging. Removal of aldehydes such as hexanal and heptanal from package headspaces.
8	Temperature control packaging	1. Non-woven plastics 2. Double-walled containers 3. Hydrofluorocarbon gas 4. Lime/water 5. Ammonium nitrate/water	Ready meals, meats, fish, poultry, and beverages	
9	Other absorber	Immobilized enzymes, ferrous salt with organic compounds	Grapefruit juice Milk products Fish and oily foods	Reduction of bitterness Removing of lactose or cholesterol Reduction or delayed production of off-flavor

Results and Discussions

In the survey we received responses from 198 student respondents. The results show that 33.3 % (66 respondent) have knowledge about innovative package, 66.66 % (132 respondent) have the little, very little and no knowledge about them, which let us know that the most respondents have insufficient knowledge about innovative packaging (active and intelligent packaging) (Fig.3.).

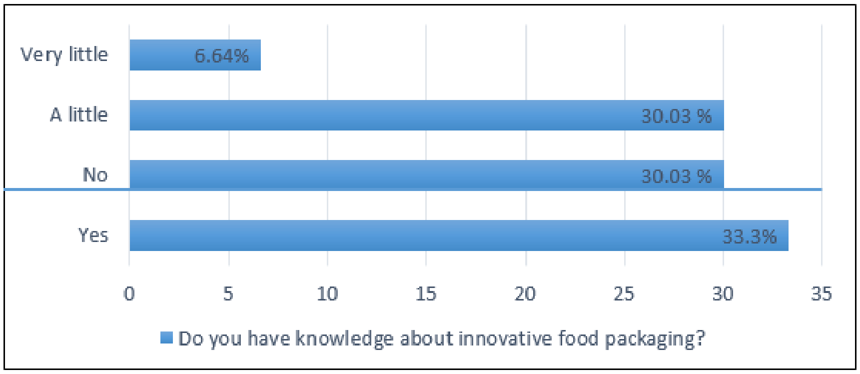

Figure 3. Results of corespondent

Conclusions

Packaging as a mechanism for food marketing is changing to suit the needs of consumers and the food industry. Active packaging systems can be successfully used to increase the shelf life of fresh and processed foods and are categorized into absorption and release and antimicrobial systems (oxygen and ethylene scavengers, moisture absorbers, flavor and odor absorber or releaser, antimicrobial and antioxidant agents, etc). This review highlights the great potential of active packaging systems and concludes that the challenges in implementing new technologies for real food applications are similar in all categories of active packaging systems discussed.

A short survey was conducted to study consumer awareness and attitudes towards active and intelligent packaging. The results show that most respondents have insufficient knowledge and understanding about innovative packaging (active and intelligent packaging). However, the recent advances discussed in this review may provide food and packaging scientists with a better understanding of the potential and benefits of active packaging technologies and, consequently, help accelerate their commercial adoption. The development and implementation of this type of packaging will depend on the acceptance and cost-effectiveness of the industry and consumers.

We recommend that, food companies in Kosovo use active packaging to increase the shelf life of food at the same time to mountain the quality and safety of fresh food and other food products. Active packaging can release substances into food. In same time, relation between food safety, active packing and information are necessary. Therefore, only authorized substances within the limits set by EU legislation (criteria of Regulation (EC) No 450/2009, Regulation (EC) No 1257/1999. 1935/2004, and Regulation EC 2023/2006) should be considered and be used.

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