SMART, ACTIVE AND SUSTAINABLE FOOD PACKAGING

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Abstract: *Change of living conditions by the developing technology has increased the expectation of the consumers. New functional features have been added to the definition of packaging and food and packaging manufacturers have sought to change physical, chemical and microbiological structure within packaged food. Developed new packaging technologies have different protection functions. They increase the shelf life of foods by providing antimicrobial activity, limiting the passage of oxygen, moisture and flavor to and from food to environment. Active packaging is the modification of the environment in the packaging so that the speed of the degradation reactions is reduced and the shelf life of the food is further prolonged.In active packaging, various additional functions are added to the package by adding various active ingredients to the packaging material or by placing them in separate tablets or sachets in the package or in the form of an intermediate layer. Smart packaging is a system that provides consumer information about food safety and quality. Examples of smart packaging with the potential to feel, monitor and signal are packages with temperature-time indicator, biosensor and special barcoded packages. Use of efficient packaging materials and technology ensures product safety and quality throughout processing, production, transport, storage and final consumption. New, active, smart and sustainable packaging technologies must be consumer-focused, reduce food losses, enhance food safety and quality, and reduce the adverse environmental effects on food packaging. This study will address the effects of smart, active and sustainable food on shelf life.*

Keywords: *Smart active packaging, food packaging, sustainability*

1. INTRODUCTION

Food packaging function, develops simple protection methods as including easiness with respect to environmental problems, material reduction, purchasing, and marketing [1].With the purpose of preserving food as close to its fresh form as possible and in a safer way and to protect the environment, new technologies are applied in the packaging of food. Food packaging technology develops continuously in order to meet the growing requirements of modern community. Main difficulties relating with the packaging of fast moving consumer goods that exist today and may exist in the future include packaging regulation, global markets, long shelf life, compliance, more safe and healthy food, environmental concerns, genuineness, and food wastes [2]. Even though they show significant variations between countries and various sectors, in Europe estimates of annual food waste production is around 89 million tons [3]. Along food supply chain, spoiling of raw meat represent a loss that can be as high as %40 [4]. Changes in sizes of packages helping consumers to purchase the right quantities and packaging design to improve food quality and shelf life are packaging optimization strategies developed to reduce food wastes [3]

With globalization besides the constant changes occuring in industrial, retail and distribution levels, the increasing consumer demand for minimal processed, more natural, fresh and convenient food products, food safety, and quality make up the important difficulties. These experiments provide a unique opportunity for packaging industry to meet the changing requests of food industry and consumers and to provide innovative solutions besides the regulating and legal requirements [5]. Active packaging of food is a good example as it provides protection of quality of packed food beyond traditional functions of package, while interaction of product and its surrounding brings with it features to improve shelf life of food and to improve safety and sensual properties [6]. Smart packaging, provides information to the processor, retailer, and/or consumer about the situation of food or the environment surrounding it [2].

Comprehensice interpretations about the usage of active and smart packaging systems are being published in recent times [2, 7, 8, 9]. In active packaging systems while it is aimed to reduce the factors decreasing the product quality, smart packaging systems provides information about the history of food product [10]. These technologies have been designed to meet the increasing demand for food safety, for long shelf life, making contribution to better stock management, and brand differentiation. Therefore, active and smart packaging promotes high food quality, while reducing wastes and the complaints of retailers and consumers and it improves general efficiency [5]. Surely, while developing new smart packaging, it will be focused more on food safety, shelf life, monitoring, verification, easiness, and sustainability of food products [11].

2. SMART PACKAGİNG TECHNİQUES

Smart packaging can be defined as system which monitors the status of packed food while providing information about quality during transportation and distribution. It can be used as having a broader meaning that includes product identity, genuineness, traceability, evidence of deceit, and protection against robbery [12].

In increasing food safety and biosafety, traceability is rather important [13]. Functional smartness samples that exist or will exist in the future will be within the packages: Protecting active integrity and avoiding food spoilage, developing food features, responding actively to changes in product or in package environment, transmitting product details, product history, or situation to the consumers, approving product verification. But smart package may not show all of these features. In accordance, smart packaging is a packaging type which has the capability to perceive and monitor the environment within or outside the package while informing the producer, retailer, and consumer about the product status [14].

1-Sensors: Sensors which are used in food packaging, show freshness of food, microbial spoilage in products (if any), oxidative rancidity, and changes depending on temperatures [15]**.** When sensors are integrated with food package, good chemicals, pathogens, and toxins can be determined [16,17]**.** Sensors can also perceive the allergenic proteints in the food [18].

Gas sensors: Gas composition at the top space of package generally changes as per food quality, structure of package, or environmental conditions [14, 2].

Gas Sensors with Fluorescence Basis: In gas sensors with fluorescence basis, fluorescent or phosphorescent paints are placed in the polymer moulds. Paint-polymer mould is applied as a thin film coating on a suitable solid support unit [15, 2].

Biosensors: Biosensors are composed of a bioreceptor and a transducer which transforms energy. Here bioreceptors are organic materials like enzymes, antigens, hormons, and nucleic acid and their task is to perceive the target parameter. Transducers are electrochemical, optical or calorimetric systems and they transform biological signals into measurable electrical tranmissions [15, 2, 12, 19].

2-Indicators: For the period when food is within the package, various indicators for features such as temperature, microbial disruption, packaging integrity, physical shock, and originality are functioning. While some of the indicators get in reaction with the food, some of them can provide information without getting in any reactions [20].

Leakage Indicators: It is the system showing existence or lack of certain gases, while it provides information about package integrity and leakages [19]. Leakage indicators change colour as a result of chemical and enzymatic reactions [14]. Indicators can be in the form of tablets, labels, and printing and they can also be formulated by coating polymer film [20].

Freshness Indicators: Freshness detectors are used for determining carbonhydrate, diacetyl, amine, amoniac, ethanol, and hydrogen sulphur which are in the packaging [21]. They are systems that work for determining metabolites and changing has concentrations as a result of violation of required conditions in the storage of food and due to microbial disruptions [22, 19]. When we classify certain freshness indicators according to their working principles, these are:

Time-temperature indicators (TTI): It is expected for these devices to imitate the change relating with a food product being subject to the same temperature, as within a specific quality parameter. Time-temperature indicators show the temperature applied during distribution with colour variations with respect to mechanical, chemical, electrochemical, ,enzymatic, or microbial changes [23]. Time-temperature indicators are labels that are prepared for providing continuity of food safety and quality and for monitoring the temperature changes in distribution and storage processes [24]**.**

These labels that are placed on the product packages change colour to show when freshness and safety of product is lost due to a deviation from the required temperature levels [25]**.** While time-temperature indicators can be added singly on each package, they can also be used as one piece attached to a whole party [20]**.** Patented TTI’s which are present in the market are: Systems which are resistant to molecular diffusion, systems based on polimerization reactions, systems based on enzymatic activities, and systems based on microbial growth [26]. For a TTI with lower cost, new enzyme reactions are developed [27]. A new type of colorimetric TTI has been developed as being based on fadable ink [25]**.** In order to monitor food quality along the frozen food chain, a new type of TTI system has been developed as based on growth and metabolic activity of *Lactobacillus sakei* [26].

3-Radio Frequency Identification (RFID): Radio frequency identification system is a system that makes identification with radio waves while providing opportunity for remote monitoring of the product [24]. Final benefits of RFID in food packaging are speeding up the stock turnover and improving monitoring [12]. By establishing RFID system at the markets, information can be automatically reached with respect to the number of a product remaining on the shelf, quantity of stock in the warehouse, products, the shelf lives of which are near expiry, and whether they are preserved under correct temperature or not.

3. ACTİCE PACKAGİNG METHODS

Active packaging systems are divided into two as “active emissive-diffuser systems” and “active emissive-retainer systens” as per the working principles. In these systems, oxygen holders, etylene holders, carbondioxide holders and emissives, moisture regulators, retainers or emissives of aroma and odour substances, ethanol, packages releasing ethanol, enzyme, and antioxidant, and antimicrobial systems [28]. Active package is an innovative concept as being a packaging type that protects product quality and interacts with product and environment and develops safety and sensual features for prolonging the shelf life or developing it.

1. Oxygen Absorbers: Top space in packed food contains gas and oxygen that is carried to a certain extent [29]. During packaging process, it is not desired to have oxygen that could arise due to insufficient evacuation and oxygen that exists in the food or packaging material can originate from poor sealing of packaging material, from the food itself or the packaging material due to micro holes, or from the air that is left in the top space as penetrating in the package.

Oxygen gas that is in the top space area interacts with the sensitive products in the package and accelerates spoilage of many food products, causes vitamin disruption and rancidity in oils, walnuts, and in oily food, and it promotes microbial growth [30]. It is required to control the level of oxygen remaining in the package by using oxygen absorbing materials that limit food spoilage rate and to release the oxygen during packaging [31, 32, 30, 33, 34]

Oxygen holder controls the level of oxygen that remains in the package and reduces it. In certain cases, oxygen being <% 0.01 can not be achieved with other packaging systems [35]. Advantages of oxygen holders: They prevent oxidation incidents [36], avoid growth of aerobic microorganisms, reduce or eliminate the need for food protectors and antioxidants, provide an economic and efficient alternative to the usage of modified atmosphere and vacuumed packageand slow down the food metabolism. Commercial presentations of oxygen cleaners are as stated: They can be included inside the package or they are the independent systems such as bag, strip, or label but they are separate components [37].

Oxygen holders should comply with the needs, features, and storage temperature of each food [38]. Packaging systems that both contain oxygen emission and antimicrobial release systems can be used for fruits and vegetables, sea products, cheese, cooked products, cereals, cookies, pizza and macaroni [39].

2. The System which Produces Carbondioxyde:

Relatively high CO_2 levels (%60 80) inhibit microbial growth on the surfaces and in accordance they prolong shelf life of packed food. Therefore, a supplementary approach for holding O_2 is the system for attaining CO_2or having an impregnated packaging structure with a second addition in the shape of a bag [40]. Since CO_2 permeability is approximately 3 to 5 times more that that of O_2 in most of the plastic films, they should be produced to protect the desired concentration within the package. High levels of CO_2 can also cause changes in taste of the products [41].

3. Ethylene Absorbers: Controlling ethylene under storage conditions, plays an important role to prolong the life many types of fresh product after harvesting [42]. One of the impact mechanisms is based on the usage of potassium permanganate which oxidizes ethylene to carbondioxyde and water. Typical permanganate content is between %4 to %6 [43]. Potassium permanganate that oxidizes ethylene, converts purple colour into brown and thus, remaining ethylene absorbing capacity shows a colour change. But due to potassium permanganate toxicity, it can not be used as having direct contact with the food. Other systems are based on the capability of certain materials to absorb ethylene either alone or with any oxidizing material [44]. As packaging material, LDPE and HDPE polyethylene films are being used in ethanol, ethyl acetate, amoniac, and hydrogen sulfide industries that can absorb ethlene films. These films keep the food as fresh for a long time and they eliminate odours [45].

4. Flavor and Odor Absorbers/Diffusers: Addition of essence and odour can improve aroma of fresh product or it can increase the desire of consumer for the food as it increases the taste of food. These flavors and odours which come out slowly and equally in packed food during shelf life or releasing, can be controlled while opening the package or preparing the food. Releasing the odours gradually, can make up for the natural loss of odor or taste of products having long shelf life [46].

5. Antimicrobials: In antimikrobial packaging systems, adding a small bag inside the package, distributing bioactive materials inside the package, coating the surfaces of packaging materials with active materials biologically, or making use of antimicrobial macromolecules having film forming features or renewable matrixes are included [7]. Most of the agents having antimicrobial features (ethanol, carbondioxyde and silver ions, chlorine dioxide, antibiotics, organic acids, essential oils, spices etc) are used with the purpose of avoiding the growth of microorganisms that could cause spoilage of food substances.

Volatie antimicrobials are seen in free packaging systems as well as in systems releasing chlorine dioxide, plant extracts, sulphur dioxide, volatile oils, [47, 48, 49] carbondioxyde and allylisothiocyanate [50, 51, 52]. Theoretical advantages of volatile antimicrobials are that they can penetrate into most of polymer and food and that they have direct contact with the food. This type of active packaging is suitable for applications where there is no contact between the food and packaging sections [33,53]. Chlorine gas can be present either in liquid or solid form. Potential application of chlorine dioxide include meat, poultry, fish, milk products, confectionery, and cooked food [7].

Sulphur dioxide is one of the most effective materials in controlling dissolution of grapeand it is much more effective than γ-radiation and heat combination. The fact that sulphur dioxide can remain in the grape and that it bleaches the grape skin form its disadvantages. Role of carbondioxyde in packaging atmosphere is related with repressing microbial growth and slowing down the breathing rate in fruits and vegetables [34]. High levels of carbondioxyde (% 10-80) are suitable for avoiding microbial growth on the product surface and for prolonging the shelf life [54]. Various protectors (sorbic acid, benzoic acid, propionic acid and its salts or bacteriocins like nisin, natural spices, silver ions, clenching materials) and substances which are used as antimicrobial materials are added to plastic films and materials. But in order for this permanent antibacterial to become active, it should have direct contact with the food [55].

6. Antioxidants: Oxidation of lipids in the food, causes a reduction in shelf life due to changes in taste and odor, tissue disruption, and reduction if food functioning and nutrition quality [56]. Food oxidation can be avoided by using oxygen holders or antioxidants substances in the packages. This type of packaging is designed to slow down or prevent the oxidation reactions that influence food quality [56]. Usage of antioxidants active film in preserving meat, can improve permanence of fresh meat and myoglobin against oxidation processes.

Migration of α tocopherol from active packaging with multi-layers, shows a delay of lipid oxidation in milk powder [54]. Antioxidants content gets reduced during storage dur to evaporation on the film and then on the surface due to diffusion of antioxidant. This reduction in the concentration of antioxidant can be avoided by adding a new layer to the film. Antioxidants can be used for oil, walnuts, butter, fresh meat, meat derivatives, flour products, fruits, and vegetables.

4. SUSTAİNABİLİTY

Concerns about climate changes and reliability of industrial raw material sources, have opened a growing market for materials with biobasis [57]. Biomaterials are natural products that are synthesised and catabolised by different organisms through biotechnical applications. When compared with the conventional synthetic products, it is seen that biomaterials can be assimilated very easily by many living organisms and as they are biocompatible, they don't cause any toxic impact in the existing organism [58].

While development and implementation of food and bioprocessing industry systems are acceptable and sustainable with respect to an effective environment, they are faced with very big difficulties with respect to the production of high quality and safe food besides nutrition [59]. In order to answer to these complex questions regarding the engineering and scientific difficulties, it is required to have new processes, products, and tools in the food industry [60]. Usage of active components being obtained from natural sources and inclusion of packaging materials like polymers which can be fragmentised biologically being put aside, it is expected for growth to continue [5].

Continuous progress that is being achieved in biotechnology, analytical chemistry, microelectronics, and material science, causes development of new smart packaging solutions. With respect to smart packaging, for having high potential, improved safety, quality and stock management and reduction in wastes, as relating with the product status, for RFID systems, biosensor integration provides information and real time information flow [61].

Another important requirement is the consumer safety warrant especially for food products which get spoiled fast. In the future, microbial growth and time-temperature indicators (TTI) which are based on physical, chemical, or enzymatic activity in the food, will reveal the product quality, safety, and shelf life in a clear way and they will be precise indicators of product quality, safety, and shelf life situation. In order to be able to answer to these complex questions regarding engineering and scientific difficulties, new processes, products, and tools are needed in the food industry [60]. Practically, smart package will be focused on perceiving the safety and quality of food and on providing information.

5. CONCLUSION

In order to reduce food spoilage and to optimize the usage of raw materials, there is a need for the implementation of packaging technologies like active and smart packaging.

With the usage of smart active packaging technologies which inspect the food status, which prolong shelf life and preserve its situation or which aims to improve it, which provides information about food, which contacts with the consumer, which makes the products of producers become different from the others, which reduces wastes, food will be continuously kept under control.

Furthermore, these packaging methods will provide efficient usage of material and energy and they will make contribution to sustainable packaging. Regarding these packaging systems, there is a need for studies to be conducted with respect to the usage of natural and recyclable healthy materials and as relating with their being adapted to smart and active packaging systems.

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