Active packaging systems for food applications

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The active food packaging is designed to prevent food degradation from microorganisms, and outside influences such as heat, light, humidity, and so on. The end user is also benefitted by having access to information about the ingredients and the nutritious values of the food package. Moreover, the consumer has the option to choose between the different sizes and shapes of packages for easier use.

The ever-increasing consumer demand and awareness of food quality and safety have contributed to emerging active and intelligent packaging technologies. The active packaging systems provide for enhanced food quality and shelf life while intelligent systems feedback additional information on the quality during transportation and storage as well. The active and intelligent packaging system market is predicted to grow up in the near future.

Active packaging

Active packaging has several advantages over traditional packaging. Active packaging uses technology that deliberately releases or absorbs compounds from the food or the space of food packaging to increase the shelf life of products by preventing moisture loss, microbial growth, and lipid oxidation. The Table 1 below summarizes the most significant advanced active packaging systems in the current food industry.

Table 1 Active packaging systems in the market

Trade name	Manufacturer	Principle	Type
Zero2	Food Science Australia, Australia	Photosensitive dye	Oxygen scavenger
Bioka	Bioka Ltd., Finland	Enzyme based	Oxygen scavenger
Freshpax, Fresh pack, Freshmax	Multisorb Technologies, USA	Iron based	Oxygen scavenger
Freshilizer	Toppan Printing Co. Ltd, Japan	Iron based	Oxygen scavenger
Oxyguard	Toyo Seikan Kaisha Ltd, Japan	Iron based	Oxygen scavenger
Ageless	Mitsubishi Gas Chemical Co. Ltd, Japan	Iron based	Oxygen scavenger
Agion	Life Materials Technology Limited, USA	Silver based	Antimicrobial packaging
Biomaster	Addmaster Limited, USA	Silver based	Antimicrobial packaging
Tenderpac	SEALPAC, Germany	Dual compartment system	Moisture absorber
Dri- Loc	Sealed Air Corporation, USA	Absorbent pad	Moisture absorber
SANICO	Laboratories STANDA,	Antifungal coating	Interleavers
Evert- Fresh	Evert-Fresh Coporation, USA	Activated zeolites	Ethylene scavenger

Various methods such as moisture and temperature control, oxygen removal, and insertion of additives like salt, carbon dioxide (CO2), sugar, conventional acids or a mixture of these items are implemented to improve the shelf life and maintain the standard of food packages [1]. The progress of active packaging has further delayed oxidation in muscle foods, controlled respiration rate in horticultural products, moisture migration and microbial growth in dried products. Further, by means of active packaging, it is possible to control the atmospheric accumulation of vaporous substances inside the package by lamination, co-extrusion, micro-perforation, coating or polymer blending [2]. Some of the active agents that are used for food packaging is shown in Figure 1.

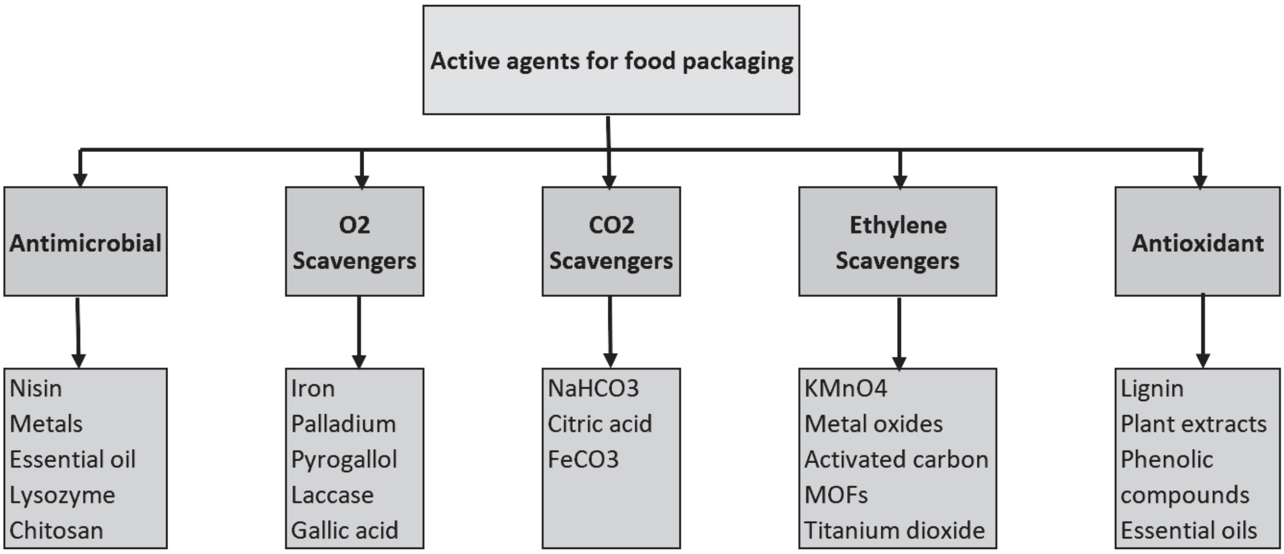

Figure 1 Active agents for food packaging systems

Antimicrobial packing

Antimicrobial packing is a system that kills or inhibits the growth of microorganisms. In this process, the growth of microorganisms present in the food or packing material is retarded or inhibited [3]. Antimicrobial materials can be added or overlaid onto food packaging medium to control the microorganism growth on food [4]. Natural antimicrobial essences can be derived from condiments like cinnamon, clove, rosemary and herbal plants like garlic, and onion. Pediocin, and nisin are few examples for natural food bio-preservatives produced by fungal and bacterial actions [5].

Antimicrobial package material is twofold. Some antimicrobial agents drift to the outer layer of the packaging medium while some antimicrobial agents are active without migrating to the outer layer of the packaging medium [6]. The application of antibacterial stuff directly on food surfaces is restricted as the active material is likely to offset during contact or spread from the outer layer to food [7]. Peptides, polyamines, enzymes and organic acids are some examples for antimicrobials with functional groups. Many polymers exhibiting antimicrobial properties like chitosan can be applied on vegetables and fruits to prevent damage caused by fungi [8]. Antimicrobial agents have been successfully incorporated to edible composite films and coatings based on polysaccharides or proteins such as starch, cellulose derivatives, chitosan, whey protein, and soy protein [9].

Oxygen scavengers

Oxygen scavengers are used widely in active packaging technology for foods today. Oxygen in a package speeds up the process of oxidative decaying of food and helps the growth of aerophilic microbes, off-flavor and smell development, colorant changes and nutrient losses and overall shelf-life security of muscle foods [10]. It is therefore necessary to control the presence of oxygen levels in food packages to restrict the rate of spoilage reactions in food. Even the use of modified atmosphere packaging (MAP) or vacuum packaging is not 100% successful for highly oxygen-sensitive foods as oxygen can permeate through the package cover in to the food package. Oxygen scavengers are employed to extract the residual oxygen after packaging and to keep the quality change of food to minimum due presence of oxygen [11]. On the other hand, the duty of oxygen absorbers is to bring down the oxygen level in the food package to less than 100 ppm. Nowadays, there are many systems of oxygen scavengers based on metallic and non-metallic compounds like iron powder oxidation, ascorbic acid oxidation, and photosensitive dye oxidation [12].

The oxygen scavengers can be mixed with MAP. Surprisingly less expensive oxygen scavengers are used to take away the residual oxygen in the MAP [13]. The structural shape of the oxygen scavenging aspect of a package can be a sachet, label, film, card or sheet. Cards and sheets can also be used in food packages to replace sachets [14] although the oxygen scavenger sachets with iron compounds have a higher capacity than the plastic films or sheets. Oxygen scavengers can be inserted into the package to protect the foods in case of accidental rupture of sachets [15].

Carbon dioxide absorbers and emitters

The microbial increase on foods inclusive of fresh meat, fish, cheese, chicken and baked products can be mitigated by way of adding carbon dioxide to the packaging surroundings [16]. Soluble gas stabilization (SGS) technology is the first step for dissolving carbon dioxide (CO_2) into the product prior to packaging in order to prolong the shelf life [17] of these foods. It's far vital to flush the ingredients with an excessive percentage of CO_2 around 80%. In this manner, CO_2 can be absorbed by the meals growing a low vacuum [18], particularly at low temperatures [19]. Excess CO_2 can be filtered out by using CO_2 scavengers. A typical example of the application of CO2 scavenger is roasted coffee packed in fully sealed packages. As CO_2 emission from coffee in a sealed package can be quite sufficient to burst the package [20], CO_2 scavengers are used to prevent the bursting of sealed coffee packages.

Moisture control

Excessive or insufficient moisture in a food package can cause fast deterioration of foods. Excessive moisture in food accelerates microbial growth [21] and changes the texture of foods. The dry powder nature of food like coffee powder or condiment powder can change to a sticky cake-like product [22] if the moisture content in the package is left uncontrolled. Therefore, the employment of a moisture regulator is a pertinent requirement to maintain the original dry nature of the food within limits. Condensation from vegetables and fruits can build up on production equipment as well supporting the risk of contamination by mold, mildew or microorganisms. A Common process involved in moisture absorption in food packaging is physisorption. During the transport of frozen fish [23] by air freight, large volumes of mats and carpets are used to absorb liquified ice. A drip-absorbent sheet includes a liquid-pervious upper layer sheet and a liquid-absorbent lower layer sheet bonded to the bottom surface of the upper layer sheet. Dehydrating agents like calcium oxide, silica gel are suited for meals like cheese, nuts and chips.

Antioxidant release

Oxidation causes deterioration of food and loss of nutritional values due to vitamin degradation. Antioxidants play a crucial role in prolonging the shelf life of food stuffs by enhancing the oxidation stability of foods. Beta-carotene, vitamins C and E, polyphenols are natural antioxidants. Coated films of Vitamin C, and E have the ability to combat the putrid odour and colour changes in oily fishes. But, most of the antioxidants found in packaging materials are artificial. The most crucial synthetic antioxidants are in the group of gallates. Gallates are combined mostly with margarine and vegetable oils to prevent them from going rancid and preserve their taste. Two other antioxidants which are not found in the above groups are butylhydroxyanisol (BHA), and butylhydroxytoluene (BHT). BHA and BHT are generally used for sweets, processed cheese, instant soups and peanut butter [24].

Ethylene scavengers

Ethylene is a gas naturally found as a plant growth hormone. The presence of very low quantities of ethylene is effective in speeding up the process of fruit ripening. Ethylene is capable of shortening the shelf life of various fruits by speeding up fruit ripening and floral senescence[25],[26]. The prolonged exposure of vegetables and fruits to ethylene can affect the quality, taste, odour and colour. Ethylene scavengers are used to limit the ethylene buildup in food packages by prolonging the shelf life and keeping the original food quality. Potassium permanganate is the most widely and commercially available ethylene scavenger, it removes ethylene by oxidizing it into ethylene glycol followed by decomposition in carbon dioxide and water. Practical application is to use zeolite and transition metals in small sachets as Ethylene scavengers.

Challenges

Prospective quality and safety benefits [27] of antimicrobial packaging have gained the interest and attention of researchers in the industry. Naturally-derived antimicrobial agents, biodegradable solutions and bio-preservatives are the areas where future research has to be mainly concentrated and aimed in microbial active packaging. Bio-degradable packaging technology has already contributed to many innovations in the packaging field with improved food quality and safety showing the practicality of bio-active functional components. More importantly, the preservation of original mechanical and barrier properties [28] of food is also essential with further development of active materials as it leads to prolong shelf life and food security.

Food waste is also another concern as loss of food can happen at different stages in the food supply chain [29]. Further research is to be carried out to enhance packaging along the entire lifecycle keeping food waste to a minimum. A commonly found weakness in packing is improper and inadequate sealing of packages. For example; a grain spillage from a sack may attract pests like rodents that can spoil the grain and make it unsuitable for human use. Regulations are to be imposed for the preservation of perishable foods during transportation and storage.

Opportunities

Nanotechnology is supposed to play a crucial role in food packaging in the future complying with safety concerns associated with packaging. Demand for appropriate and safe advanced packaging stuff is a key requirement according to Majid et al. [30]. These materials are intended to administer the liberation of active agents in combination with detectors implanted in the packaging system.

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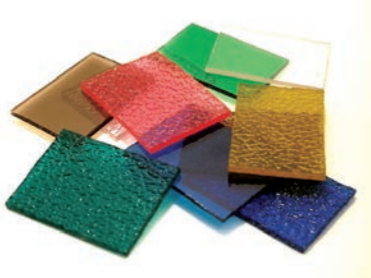

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