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Technological Innovations in Modern Food Packaging Systems; Active Packaging

Suhail Nazir Bhat* and Suman Vikas Bhat

Department of Food Technology, Islamic University of Science and Technology, Awantipora, Kashmir, India

***Corresponding Author:** Suhail Nazir Bhat, Department of Food Technology, Islamic University of Science and Technology, Awantipora, Kashmir, India

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Abstract

Active packaging can be defined as "packaging in which subsidiary constituents have been deliberately included in or on either the packaging material or the package headspace to enhance the performance of the package system. An example of this packaging system is when a plastic package has adequate moisture barrier but an inadequate oxygen barrier. Active packaging solutions could be the inclusion of an oxygen scavenger, or an antimicrobial agent if microbial growth is the quality-limiting variable.

Keywords: *Food Packaging; Active Packaging*

Introduction

The basic function of packaging is to contain and ensure safety of a food product until it is consumed by consumer. Packaging is the means of ensuring safe delivery of a food product to ultimate consumer in sound condition and at affordable price [1]. Packaging also helps in preserving foods, maintaining quality and acceptability of a product from point of view of consumer. Thus shelf-life of a food product is largely dependent on the type of package, its condition and integrity. The other functions may include brand communication, convenience and promotion. In 1980s the concept of active packaging started giving a new dimension to research in packaging technology. Active packaging is one of the innovative food packaging concepts that has been introduced to cope up with the changing consumer trends, lifestyle and to meet market trends. The term Active Packaging was first used by Labuza [2]. Active packaging refers to incorporation of certain additives into packaging film or within the packaging container with the aim of maintaining and extending the shelf life [3]. Packaging can be termed active when it performs some desired role in food preservation other than providing an inert barrier to external conditions [4,5]. The beauty of active and smart packaging includes elongated shelf life, indication of freshness and spoilage which provided a concrete solution to food being packaged and stored for astronauts in space and for military-ration purposes [6]. Active packaging involves use of either absorbing system or releasing systems that regulate various properties and deteriorative reactions in foods. The absorbing systems (scavengers) include oxygen, carbon dioxide, ethylene and/or flavor/odor absorbing systems and emitters (releasers) may include to those of releasing ethanol, antioxidants, antimicrobials and other preservatives. This had led to fairly high elongation of shelf life of various food products. The unique deteriorative mechanisms in different food products have been accordingly treated to achieve higher product shelf life. Active packaging is typically found in two types of systems; sachets and pads which are placed inside packages and active ingredients that are incorporated directly into packaging materials. Oxygen scavengers are by far the most widely used active packaging systems. Oxygen scavenging systems adsorb the oxygen in package thereby reducing the rate of deteriorative reactions like lipid oxidation, oxidation of flavors, vitamins and decreasing the rate of breakdown. Active packaging systems have been widely used in fruits and vegetables, coffee, meat products, pizzas, pastas, baked goods, alcoholic beverages, dairy products etc. from last few decades.

Active packaging systems

Oxygen scavengers

Oxygen is detrimental to foods owing to its high oxidizing capability. The various deteriorative reactions caused by oxygen include oxidative rancidity, oxidation of coloring agents and vitamins, growth of aerobic microorganisms [7]. Oxygen scavenging systems have been used to decrease the concentration of oxygen inside the package thereby prevention of deteriorative reactions and growth of aerobic microbes. Lower oxygen concentration decreases the rate of respiration in fruits and vegetables which has direct relation with the shelf life for these products [8].

Oxygen scavengers are the most widely used commercially important active packaging systems. The global market for oxygen scavengers was estimated to be 10 billion units in Japan, several hundred million in USA, tens of millions in Europe in 1996 [7,9].

Oxygen scavengers are usually composed up of sachets containing powdered iron or ascorbic acid. Iron based scavengers have a problem of rejection by metal detectors and do not pass during inspection on most packaging lines and in these incidences, non-metallic detectors like ascorbic acid is advantageous [9]. Other nonmetallic oxygen scavengers like ascorbic acid, ascorbate salts or catechol; enzymes like glucose oxidase, ethanol oxidase are also used to overcome the above problem (Hurme, 1996). In case of liquid foods like wine, beer and other beverages, iron based sachets cannot be used as moisture decreases the activity of these components. Thus, various nonmetallic and organometallic based systems are used which are incorporated into bottle closures and caps or blended into polymer materials to scavenge any oxygen present in bottle headspace and any entering oxygen is also scavenged [10].

Function	Reactant	Japanese Product	Manufacturer
$O_2\downarrow$	Iron	Ageless® Z-PK	Mitsubishi
		Vitalon™	Toagosei
		Ageless® Z	Mitsubishi
		Keplon™	Keplon
		Ageless® S	Mitsubishi
		Secule™ CA	Nippon Soda
		Ageless® SS	Mitsubishi
		Ageless® FX	Mitsubishi
		Vitalon® LTM	Toagosei
$O_2\downarrow$	Catechol	Tamotsu™ A	Oji Kako
		Tamotsu™ P	Oji Kako
$O_2\downarrow$ and $CO_2\downarrow$	Iron and calcium	Ageless® E	Mitsubishi
$O_2\downarrow$ and $CO_2\uparrow$	Ascorbic acid Organic acid and Iron	Ageless® G	Mitsubishi
		Toppan™ C	Toppan
		Vitalon™ GMA	Toagosei
$O_2\downarrow$ and Ethanol $\uparrow$	Iron and ethanol on zeolite	Negamold™ (antimycotic)	Toppan

Table 1: *Oxygen absorbers used in Japan.*

Source: [17].

Carbon dioxide emitters/absorbers

Since carbon dioxide has negative impact on the growth of microorganisms, higher concentration (60 - 80%) can be used to suppress microbial activity and prolong shelf life of foods [11]. Oxygen free environment alone is insufficient to retard and control the growth of *Staphylococcus aureus, Vibrio species, E. coli, Bacillus cereus, Enterococcus faecalis* at ambient temperatures [12]. Thus, in order to achieve the effective inhibition of microorganisms, oxygen scavenging systems has to be backed up with thermal processing, or refrigerated storage, or using carbon dioxide enriched atmosphere. Commercially carbon dioxide emitters and label devices can be used either alone or combined with oxygen scavenger. The higher carbon dioxide concentration apart from preventing microbial growth also prevents pack collapse due to lower internal pressure caused by absorption of oxygen by oxygen scavenging systems. The most effective and advanced technique is the use of oxygen absorbing and carbon dioxide emitting systems together.

The carbon dioxide absorbing sachets, dual-action oxygen and carbon dioxide scavenging systems made of activated charcoal, calcium oxide etc. are used to scavenge carbon dioxide. Carbon dioxide absorbing sachets are widely used to remove carbon dioxide gas produced in fresh roasted and ground coffee [10]. As coffee is prone to moisture absorption and loss of desirable volatile aroma and flavor when left open, so it is packaged hermetically in air tight packages. However, if coffee is hermetically sealed in packs directly after roasting, the carbon dioxide released after roasting will build up within packs and cause them to burst (Subramanian, 1998). In such cases the carbon dioxide scavengers maintain integrity of package and prevent bursting of packs due to high internal pressure.

Moisture absorbers/regulators

High moisture content in foods is the major cause of spoilage. The water from food evaporates during storage and condenses back on the surface of packet thereby increasing the amount of free water in food, increasing chances for microbial growth, loss of flavor and texture. Microbial growth is proliferated at higher water activities (a_w) therefore decrease the shelf life of foods [13]. Moisture absorbing sachets, pads, sheets and blankets are manufactured by various companies. The use of desiccants like silica gel, calcium oxide (CaO), clay is widely seen in dried products like snack foods, cereals and cereal products. For foods with high water activities (a_w) like meat, poultry, fish and fresh produce, drip adsorbent sheets such as Thermarite® or Peaksorb® are used [14]. Other examples of moisture absorbers are given in table 2. Humectants and desiccants have been successfully used for moisture control in wide range of foods such as cheeses, meats, chips, nuts, corn, candies, gums and spices. Silica gel, CaO, molecular sieves and natural clays are often provided in Tyvek™ sachets [15].

Ethanol emitters

The antimicrobial properties of ethanol are widely known. Concentrated ethanol (95%) is especially good for inhibiting the growth of yeast, mold and certain bacteria as well. The use of ethanol emitting systems has been employed widely in preventing mold growth in bread and other bakery products. Ethyl alcohol (C_2H_5OH) has been shown to increase the shelf life of bread when sprayed on the surface of food product prior to packaging (Sieler, 1978). Ethanol releasing technology was first developed and used in Japan with the use of ethanol immobilized (micro-encapsulated) sachets. Ethanol emitting systems under trade name Ethicap® or Antimold® 102 is sachet placed alongside food and it releases ethanol vapor into the head space. The ethanol vapor (0.5 - 2.5% (v/v)) then condenses on the food surface and acts as microbial inhibitor [16]. The size and capacity of sachet depends upon the weight of food, a_w of food and desired shelf life of the product. Ethanol vapor generation systems have shown to be effective in controlling ten species of molds including *Aspergillus* and *Penicillium* species, various species of bacteria including *Salmonella*, *Staphylococcus* and *Escherichia coli* and the species of spoilage yeast (Smith., *et al.* 1990). Ethanol has been shown to prevent staling and oxidative deterioration in bread. The permissible level of ethanol as a food additive should not exceed 2% of the weight of product (CFR, 1990).

System/ Action	Substance	Organizational source
Ethylene absorbing	• Activated carbon/potassium permanganate	• Kurray/ Nippon (Japan) • Greener (Japan)
Ethanol emitting	• Micro-encapsulated ethanol	• Freund (Japan)
Moisture absorbing	• Polyvinyl alcohol encapsulation • Silica gel • Clay-based	• Grace Chemical (Davison) • Capital Specialty Plastics • Multisorb Technologies • Sud-Cheme Performance Packaging
Antimicrobials	• Sorbates • Benzoates • Propionates • Silver salts • Sulfur and mercurial compounds • Bacteriocins • Sub-micrometer cell wall penetrants • Zeolites • Chlorine dioxide	• Mitsubhi Gas Chemical (Japan) • Microban Products • Various from Japan • Mitsubhi Gas Chemical (Japan) • Shinagawa Fuel (Japan) • Tachyon Energy (Japan) • Bernard Technologies • Engelhard Corp.
Antioxidant releasing	• BHA/BHT • TBHQ • Vitamin C or E	• Roche
Flavor/Odor absorbing	• Activated carbon • Sodium bicarbonate	• Arm and Hammer • Cabot
Chemical stablizers	• Tocopherol or Vitamin E	• Roche

Table 2: *Types of active packaging systems with mode of action and representative manufactures (Excluding oxygen scavengers).*

Source: [17].

Anti-microbial/preservative releasers

Use of antimicrobial agents incorporated into packaging materials has increased during last few years for preservation of meat, fish, bread, cheese, fruits and vegetables [10]. This innovative packaging system is capable of controlled release of antimicrobial agents when microbial growth occurs in foods. The main mechanism of action is to extend the lag phase of microbial cells thereby preventing their multiplication. Antimicrobials incorporated in food packages extend the shelf-life of these products. In one such system, known as "BioSwitch", an antimicrobial is released on a command when microbial growth occurs inside packet (Jong., *et al*. 2005). These systems utilize the change in environmental conditions like pH, temperature and accordingly release antimicrobials. Many other synthetic and naturally occurring preservatives have been tested for microbial activity in plastic and edible films [7,17]. These include organic acids, e.g. propionate, benzoate and sorbate, bacteriocins, e.g. nisin, spice and herb extracts, e.g. from rosemary, cloves, horseradish, mustard, cinnamon and thyme, enzymes, e.g. peroxidase, lysozyme and glucose oxidase, chelating agents, e.g. EDTA, inorganic acids, e.g. sulphur dioxide and chlorine dioxide and antifungal agents, e.g. imazalil and benomyl [10].

Antioxidant releasers

Antioxidants have been widely used in high lipid foods and dried products to improve stability of these foods to lipid oxidation and extend shelf-life [18]. Additives such as butylhydroxyanisole (BHA) and butylhydroxytoluene (BHT) were incorporated into wax liners for the cereal industry in early 1980s [16]. The use of BHA and BHT has been employed in snack foods and cereal flakes (breakfast cereals) using waxed paper liners [16]. Now Day [10]. recent trends are the use of edible films containing antioxidants. These films are made up of edible materials like milk proteins, crop proteins, starches and gums. The use of vitamin E (tocopherol) is a substitute for inorganic oxidants like BHA/BHT (Newcorn, 1997). The essential oils extracted from rosemary are believed to have good antioxidant properties. These antioxidants have been immobilized on polypropylene (PP) films are a good substitute for BHA and BHT.

Ethylene absorbers

Ethylene which is a plant growth regulator has different physiological effects on fruits and vegetables. It increases the rate of respiration and thereby causes ripening in fruits. Higher ethylene concentrations promote quick maturity, ripening and softening of fruit tissues thereby decreasing shelf life. It has also considerable effects on vegetables where yellowing of tissues occurs due to loss of chlorophyll.

The ethanol scavenging systems are mainly based upon potassium permanganate ($KMnO_4$), which oxidizes ethylene to acetate and alcohol. This is detected by change in color of $KMnO_4$ from purple to brown [10]. Ethylene absorption has also been done by the use of activated sachets containing activated carbon/charcoal. Sachets containing activated carbon can be incorporated into corrugated fiber board boxes and paper bags to scavenge ethylene. A number of alternative ethylene-scavenging systems have been proposed. Activated charcoal alone or after impregnation with bromine is another ethylene absorbing system. Also, bentonite, Kieselguhr and crystalline aluminosilicates, e.g. zeolites, have been reported capable of adsorbing ethylene [15]. In japan, ethylene scavengers on trade name "Everfresh", based upon Oya-Stone have been used. Oya-Stone is a zeolite with a claimed affinity for ethylene and carbon dioxide Films containing Oya-Stone have been extruded with polyethylene into pouches used to contain ethylene-generating fruit or vegetables [19,20].

Conclusion

Active packaging is an innovative and exciting technology which has potential of preserving and extending shelf-life of wide range of products.

Active packaging systems for packaging foods can help to reduce the level of additives to a large extent from foods.

Active packaging systems have mainly been used in Japan and USA, while the poor countries like India are still lacking such facilities. This is mainly because of the high costs of technology and production of such materials. Research programs aimed at developing cost effective active packaging systems have to be focused on.

The safety and regulatory issues associated with food packaging may limit the developments in active packaging technology. The use of harmless compounds and substitution of inorganic chemicals with organic materials like edible films, antioxidants and antimicrobials from herb extracts have to be encouraged.

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