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REVIEW ARTICLE

BIO ACTIVE PACKAGING FOR HEALTHIER FOODS

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ABSTRACT

The packaging scenario and requirements for processed foods world over is changing fast. This is not only with regard to materials, forms, systems and machinery, but also legal aspects closely linked with environmental equilibrium and maintenance as well. Among these developments, the "Packaging of Future" is expected to do more than just contain and protect. One of the novel technologies is bio-active packaging where the package itself smartly imparts the functional properties in foods. This literature throws light on some of the basis of bio-active packaging and techniques involved in the manufacturing of packaging films for foods.

INTRODUCTION

Functional foods have been the topic of considerable interest in the food and nutrition industry for years, but the term currently lacks a common definition. A practical definition adopted here includes products, in food or drink form, that influence specific functions in the body and thereby offer benefits for health, well-being, or performance beyond their regular nutritional value. Recent innovative technological developments in the production of functional foods, whose bioactive principles and actuators are devised to be contained within the packaging or coating materials (Amparo, 2003). Therefore, it gives rise to a novel conceptual approach to develop functional foods, while setting the roots of a new packaging technology termed as bioactive packaging, in which, a food package or coating is given the unique role of enhancing food impact over the consumer's health. The functional, or more precisely, bioactive packaging materials would thus be capable of withholding desired bioactive principles in optimum conditions until their eventual release into the food product either through controlled or fast release during storage, or just before consumption (Rowan, 2001). Now it is important to state the differences between active and bioactive packaging technologies. The main difference between the well-known active packaging technologies is that while active packaging primarily deals with maintaining or increasing quality and safety of packaged foods, i.e. shelf life of packaged food products, bioactive packaging has a direct impact on the health of the consumer by generating healthier packaged foods (Amparo, 2003).

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Industrial Impact

In the food industry there are a number of limitations and complications during processing and manufacture of the majority of commercial functional foods which are presented with the bioactive components contained within compatible foods. Some of the difficulties are the loss of product functionality during processing, storage, and commercialization. For instance, probiotic bacteria counts are known to substantially decrease as a consequence of processing, during product storage by oxidation, and also during their passage through the gastrointestinal tract. The next difficulty is that the functional substance is not often compatible with the food matrix. This is the case, for example, of fat soluble vitamins in aqueous foods. Sometimes the added bioactive compound can induce the development of undesirable flavors or strange odors. The modification of textural characteristics as a consequence of the added compound affects commercial appearance of the product. In the case of enzymes, due to their sensitivity to processing and to trace levels of inhibitors, the dissolved enzymes may suffer inactivation. The production costs are expensive due to the incorporation of active components (Falk, 2004). Nowadays, the most popular functional foods are those containing probiotics and prebiotics, but the range of application is limited to certain food products, mostly fermented milk products, because of the actual technological barriers concerning the processing of those bioactive substances (Rowan, 2001). Even in these more established products, surveys show that in yoghurt preparations, there are large fluctuations and poor viability of probiotic bacteria, and especially of bifidobacteria during product storage or in their passage through the digestive tract after consumption (Schillinger, 1999). Currently, industrial demand for technologies ensuring the stability of bioactive compounds in foods remains strong. In this way, new technologies such as micro- and nano encapsulation provide promising prospects for improved performance of the functional ingredients. Thus this field of functional ingredients throws light on the healthy and safe delivery of quality foods (Rowan, 2001).

Thus, the venture of the work is to gather concepts for the novel technological approach, in which innovative functional packaging to avoid the barriers and limitations in the manufacturing of functional foods are discussed. Some of these innovative concepts can be carried out by:

(a) Integration and controlled release of bioactive components packaging systems
(b) Micro- and nano encapsulation of these active substances in the packaging
(c) Packaging provided with enzymatic activity
(d) Anti microbial Bioactive agent incorporation in packaging of foods.
(e) The development of food packaging systems using the functional probiotics.

Integration and controlled release of bioactive components packaging systems

One of the most important functions of the package is to maintain or increase food quality and safety. But some of plastic packages are not readily recyclable and are not environmentally sustainable causing a number of health hazards. Thus, it is highly desirable to develop biodegradable matrixes capable of safe and long shelf-life integration of bioactive substances. As biodegradable materials, synthetic biodegradable polymers, biomass-derived thermoplastics, novel nano biocomposites, etc are the most suitable materials for the controlled release of substances. The functional substances which are thought most suitable for their incorporation in the package wall are phytochemicals, vitamins, nanofibers and prebiotics. Phytochemicals are non-nutritive plant chemicals that contain protective, disease-preventing compounds. More than 900 different phytochemicals have been identified as components of foods (Amparo, 2003). They are associated with the prevention of cancer, diabetes, cardiovascular disease, and hypertension. Many phytochemicals are polyphenolic compounds with antioxidant activity. The antioxidative effect of phenolics in functional foods is due to a direct free radical scavenging activity and an indirect effect arising from chelation of prooxidant metal ions (Halliwell, 1996). Vitamins are essential for good health. Food can supply all the vitamin requirements provided that the diet is adequate and well-balanced. In some cases the vitamins are lost due high heat treatment processing like blanching sterilization etc. The modern lifestyle also causes greater impact in unbalanced diet (Shahidi, 2000). Dietary fiber consists of the structural and storage polysaccharides and lignin in plants that are not digested in the human stomach and small intestine (Amparo, 2003). The concept of prebiotic arose from the observation that inulin and fructo-oligosaccharides selectively stimulate the growth of bifidobacteria which are considered to be beneficial for human health. A prebiotic is considered to be any food component that escapes digestion in the small intestine and enters the colon, where it may serve as a growth substrate for intestinal bacteria (Roberfroid, 2001). Other biopolymers such as chitosan and some chitosan derivatives can also have a prebiotic character are used as micro- or nanofibers or as encapsulating means of other components (Agullo *et al.*, 2003).

Techniques

The selection of the materials to be used either in the form of packages or as coatings is crucial because in addition to the main role of containing the functional substance to exert a protecting function, maintaining and assuring the quality of the packaged food is essential. The process of film fabrication has to be adapted to the technological limitations of each bioactive compound, i.e. for those substances sensitive to high temperatures, such as certain vitamins, low process temperatures have to be used for casting or extruding the materials (Brody 2005). The release of substances can be activated and controlled by several parameters such as humidity, pH, temperature control etc. Another favorable method to achieve controlled release is by using packaging materials such as closure caps, sachets attached to multilayer structures in the form of full packaging walls. Feasible multilayer bioactive structure could include three layers, i.e. control layer/matrix layer/barrier tie layer. The inner control layer is thought to govern controlled release of the bioactive and exert a barrier function to protect the bioactive from direct food or food moisture contact before the action is triggered (Brody, 2005). The matrix layer contains the functional substance in a safe and, upon potentially long shelf-life, latent conditions and the barrier third layer prevents migration of the agent toward the outside of the package and printability. The greatest limitation of this technology is that, as the functional substances proposed for these packages are nonvolatile compounds, direct contact between the package and the food surface is needed.

Encapsulation techniques

Encapsulation is defined as a technology for packaging solids, liquids, or gaseous substances in miniature, sealed capsules that can release their contents at controlled rates under specific conditions. Encapsulation involves the incorporation of food ingredients, enzymes, cells or other materials in small capsules. Applications for this technique have increased in the food industry because the encapsulated materials can be protected from moisture, heat or other extreme conditions, thus enhancing their stability and viability (Jimenez *et al*., 2004). Various techniques are employed to form the capsules, including spray drying, spray chilling or spray cooling, extrusion coating, fluidized bed coating, liposome entrapment, coacervation, inclusion complexation, centrifugal extrusion and rotational suspension separation (Gibbs *et al*., 1999). Fats, starches, dextrin's, alginates, protein and lipid materials can be employed as encapsulating materials. In food industry, the most common method is by solvent activated release. This technique is not a liable in economical point of view.

Enzymatic packaging

The immobilization of enzymes in materials was initially applied in food production lines (Katchalski-Katzir, 1993; Mosbach, 1980) as a result of the numerous technological advantages over the use of free enzymes such as reusability, improved stability to temperature etc. However, more recently, these technologies are also being considered for packaging applications (Appendini and Hotchkiss, 1997). The objective of these bioactive materials is to catalyse a reaction, which is considered beneficial from a nutritional point of view, i.e., decreasing the concentration of a non-desired food constituent or producing a food substance beneficial to the health of the consumer. Soares and Hotchkiss (1998) immobilized naringinase in a plastic package. The results indicated that the grapefruit juice reduced its bitterness by hydrolysis of naringine, a bitter principle of citrus juices. Another enzymatically bioactive packaging concept already described (Brody and Budny, 1995) consists the binding of b-galactosidase and cholesterol reductase in the package walls for the hydrolysis of lactose and cholesterol, respectively. For example, UHT milk could be packaged in a b-galactosidase bioactive package and during storage, the product would transform into a low-lactose or free-lactose product. This processing plant inside the package appears to be a very promising technology. The techniques already used for the immobilization of enzymes can be divided into five different categories:

- Adsorption
- Ionic binding
- Covalent attachment
- Cross linking
- Entrapment /encapsulation.

The method of immobilization, covalent attachment and crosslinking often involve either the modification of the biopolymer surface or the use of toxic chemicals, such as glutaraldehyde, which is usually unsuited for applications in food. The mechanisms by which enzymes can be immobilized on clay minerals include cation exchange, physical adsorption and ionic binding (Sarkar *et al*., 1989). An entrapment method was used by to make an enzyme-based oxygen scavenger laminate. The enzyme solution, containing various additives, was applied on a paper carrier which was placed between two polyethylene films. The laminate was then heated under pressure and the system proved to be successful and no significant (Andersson *et al*., 2002).

Bioactive agents (BA)

Bioactive agents used in bioactive polymer systems can be defined as substances which give the desirable biological effect to surrounding environment. Apart from its specific biological activity in the system, the physicochemical properties of the bioactive agent such as solubility, reactivity and compatibility are important factors for the activity (Caliceti, 1999). Generally, they can be classified into two groups namely, natural and chemical. For heat-sensitive bioactive agents such as enzyme, protein and volatile agents, solvent compounding may be the appropriate incorporation method.

Bioactive agents for food packaging

BA is applied for food packaging, e.g. as antimicrobials, biocatalysts, absorbers or scavengers. The most of them are used in practice as antimicrobial agents. In order to use BA for food, they must be non-toxic or regulated.

i. Chemical bioactive agents

Chemical bioactive agents include organic acids, fungicides, alcohols and antibiotics and all of them should be food-grade. In the packed food system, they can be added directly to food ingredients, incorporated into packaging material as well as placed in the atmosphere of head-space. Organic acids such as sorbic acid, lactic acid, acetic acid, citric acid and propionic acids, their salts as well as anhydrides are very common antimicrobial agents with high efficacy and cost effectiveness, and approved as additives for certain foods. They are effective against various types of microorganisms and correct selection is required for efficient antimicrobial activity. In some cases, either mixture of organic acids or combination of organic acid with other bioactive compound has stronger antimicrobial activity than a single organic acid (De Kruijf, 2003). Ethanol has strong activity against bacteria and fungus; however, it is not effective for the growth of yeast. Desiccating agents such as silica gel, natural clays and calcium dioxide are used for high moisture foods and pharmaceutics. They can be incorporated in packaging materials, also in the form of porous sachets . Potassium permanganate is used in packaging systems as an ethylene removing agent, which oxidizes ethylene to acetate and ethanol. It is mostly applied in form of sachets, may also be incorporated into packaging materials (De Kruijf, 2003). For many decades, different types of metals such as copper, zinc, titanium, magnesium, gold and silver have been identified as antimicrobial agents used in many fields including biomedical, food packaging, etc. Nowadays, their related nanoparticles have received increasing attention particularly; silver nanoparticles have been demonstrated as the most effective antimicrobial agent against various microorganisms. Of all metallic antimicrobial compounds, silver-substituted zeolites are the most widely used polymer additive for food packaging, especially in Japan. Some silver- substituted zeolites are commercialized (Brackett, 2002).

Gaseous antimicrobials are known as beneficial due to their vaporization and penetration compared to solid and solute types of chemical antimicrobials. According to literature review, the uses of chlorine dioxide and ozone have been approved by FDA and can be incorporated into packaging materials (Brackett, 2002). Antibiotics are not permitted as package additives for the purpose of antimicrobial activity; however, they may be applied for short-term use of medical devices and other non-food products .The use of antioxidants is desirable for the food packaging due to its efficient antifungal activity. Natural antioxidants such as α-tocopherol and ascorbic acid are important in food applications concerning the use of food chemicals.

ii. Natural bioactive agents

Some bacteriocins including nisin, lacticins, pediocins and diolococcin produced by microorganisms are capable of developing activity in order to inhibit the growth of pathogenic microorganisms (Branen, 1993). Particularly, nisin is an effective bactericidal against Gram-negative and Gram-positive bacteria and it has been accepted as a food additive by the FDA and WHO (Helander *et al*., 2001). In addition, nisin has surface-active molecules that may be suitable for adsorption to solid surface used for antibacterial packaging (Branen,. 1993). The activity and release of nisin from the film strongly depends on pH and temperature; precisely a lower pH and a higher temperature were most effective for the migration from the film (Brackett, 2002). Some other natural bioactive agents, enzymes can be added directly to food product or can be incorporated into packaging material, in which the enzymes must be immobilized (Helander *et al*., 2001). In the food packaging area, some enzymes such as immobilized naringinase in plastic packaging are intended for reduction of grapefruit bitterness, and lactase is suitable for low-lactose or free-lactose milk, and cholesterol reductase is intended for the hydrolysis of cholesterol in packaged food. (Brackett, 2002).Moreover, enzymes with antimicrobial properties control the amount of oxygen against aerobic bacteria or direct antimicrobial activity into on microorganisms present in packaged food. Natural plant extracts such as grapefruit seed, cinnamon, horseradish and clove have received increasing attention as regards their antimicrobial activity against spoilage and pathogenic bacteria, therefore, a great deal of natural extracts is expected due to this advantage when compared to chemical active agents. Grapefruit seed extract has a broad range of antimicrobial activity which was stable at high temperatures of up to 120°C (Brackett, 2002). The horseradish contains volatile allyl isothiocyanate which shows antimicrobial activity against several fungi and bacteria.

Probiotics

There is growing evidence that the maintenance of healthy gut microflora may provide protection against gastrointestinal (GI) disorders including gastrointestinal infections and bowel diseases (Fuller, 1989). Pro and prebiotics are benefited on alleviation of lactose maldigestion, increased resistance to gut invasion by pathogenic species of bacteria, stimulation of the immune system and possible protection against colon cancer (Zubillaga *et al*., 2001). Both pro- and prebiotics are intended to modify the gastrointestinal microflora in such a way that bactericidal activities advantageous to the host are stimulated and those adverse to host health are suppressed. But before a probiotic can benefit human health it must fulfill several criteria. It must have good technological properties so that it can be manufactured and incorporated into food products without losing viability and functionality or creating unpleasant flavours or textures. Furthermore, it has been observed that probiotics are only effective if the dosage is sufficiently high. It is essential that products labeled with any health claims meet the criterion of a minimum of 10^6 CFU/ml of probiotic bacteria at the expiry date (Sanders and Veld, 1999). Encapsulation is the most widely used technology which helps to ensure the viability and it is released directly to the product. It is mainly done in hydrocolloid beads entraps or immobilizes the cells within the bead matrix, which in turn provides protection in such an environment (Krasaekoopt *et al*., 2003). The most widely used encapsulating material is alginate, a linear heteropolysaccharide of D-mannuronic and L-guluronic acid extracted from various species of algae. Alginate beads can be formed by both extrusion and emulsion methods (Krasaekoopt *et al*., 2003). The use of alginate is favoured because of its low cost, simplicity, and biocompatibility.

Conclusion

Despite the extended shelf-life of refrigerated products stored under vacuum- packed or MAP conditions, there is an increasing concern about the growth and survival of microaerophilic psychotrophic pathogens. Thus, additional methods should be used to ensure the safety of such products. Smart, interactive and bio active packaging are terms that have been used to describe the innovative concept of package structures. Thus bioactive packaging is thus a novel set of technologies designed to give response to a number of issues related to the feasibility, stability and bioactivity of functional ingredients for the food industry.

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