Edible films and coatings- A review of current scenario in the food industry

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Abstract: Edible Films and Coatings are the upcoming future of food processing. They offer a vast promise and scope in minimal processing and other technologies used for meat, poultry, confectionery fruits and vegetables to name a few. They have found wide ranging applications in flavour encapsulation and supplementation too. The present review focuses on the Structure and functions of Edible Films, Possible components of edible coatings, Importance of Edible films and Coatings and endeavours to study the Effect of edible coatings and their lack thereof on foods, Applications and preparation of edible films, Delivery of Food Additives, Antimicrobials, active ingredients using edible films and coatings and the very important application of Edible coatings and films for Flavour Encapsulation.

Introduction

Why do we need Edible Films?

Most foods consumed come directly from nature, and many of them can be eaten immediately. Edible Films and Coatings have been used to protect foodstuffs for some time now. Edible Films and Coatings such as wax on various fruits, have been used from centuries to prevent loss of moisture and to create shiny surface. Other examples include the protection of cuts of meat against desiccation and gaseous exchanges by coating them with fat(which has been practised in Europe since the 16th century).

For some 40 years, much research has been carried out on the development and use of films or edible coatings to improve the preservation quality of various fresh food stuffs. Some procedures- such as Micro packing of powders in gelatin capsules, the use of flat chocolate or cocoa based barrier layer to avoid soaking in ice-creams cones has been widespread.

Naturally, we can take food products from the trees , vine or ground, however, with increased transportation and distribution systems, storage needs and advent of even larger supermarkets and warehouses stores, foods are not consumed just in orchards, on the field, in the farmhouse, or close to the processing facilities. It takes a considerable amount of time for a food product to reach the table of the consumer. During these time consuming steps involved in handling, transportation and storage, products start to deteriorate, dehydrate and lose appearance, flavour and nutritional value. If no special protection is provided damage can occur within hours or days, even if this damage is not immediately visible.

Edible Coatings or Films

Any type of material used for enrobing(i.e. coating or wrapping) various foods to extend shelf life of the product that may be eaten together with food or without further removal is considered as an ‘Edible Coating or Film'. In particular, they must be pleasant to taste, contain no toxic, allergic and non-toxic, and non digestible components. It must provide structural stability and prevent mechanical damage during transportation, handling and storage. It should have good adhesion to the surface of food to be protected providing uniform coverage. It must control water migration both in and out of protected food to maintain desired moisture content. It should be easily soluble or easily dispersed in the mouth. They can be used to cover the product or to divide one constituent of the foodstuff from the other. Their protective and mechanical properties may be reinforced by the addition of additives such as Plasticizers or antioxidants or antimicrobial agents.

The use of edible films and coatings does not generally imply dispensing with inedible packaging. However, it may be possible to use lower quality, more economical materials for the latter. In fact, edible films constitute a complimentary and sometimes vital element in managing the quality and stability of many foods.

Edible films provide replacement and fortification of natural layers to prevent moisture losses, while selectively allowing for controlled exchange of important gases such as oxygen, carbon dioxide and ethylene which are involved in respiration processes. A film or coating also provides surface sterility and prevent loss of other important components. Generally, its thickness is less than 0.3mm.

Effect of Edible Coatings or their lack thereof!

Today the most widely used commercial method for long range protection is interim storage at low temperature(4-8°C), especially for lightly processed foods. Lowering temperatures generally decreases undesirable enzymatic activities, although temperature decreases down to 0-5°C may actually lead to increase in respiration rate and ethylene production**(Eaks 1980).**

Below 0°C, growth of moulds is inhibited, but even this low temperature does not fully eliminate undesirable chemical and physiological reactions **(Fennema 1993).**

For example, fruits and vegetables native to tropical climates experience harmful chilling effects such as damage to cell membranes at temperature 10-12°C. In addition, some cold tolerant pathogenic microorganisms are able to grow under refrigeration conditions.

Accordingly, an increased amount of research has been conducted over the past 50 years to encase food products, such that rates of migration of molecules involved in degradation processes are maintained at natural levels and/or minimized.

Edible films are being used for a variety of purposes within a multitude of food systems, even though this fact is not fully realized by the consumers. The shiny surface of an apple in a supermarket is not provided by the nature. Some candies (e.g. M and M's) are coated with shellac to increase product shelf life and to provide desired glaze. Even French fries are frequently coated to provide protection during cold storage before frying, control of water loss during frying. Edible films may also be used to limit uptake of oil and fats during frying processes. **(Feeney et. al. 1992; Polanski 1993).**

Quality of various other food products such as meat, pies, and confectionery can also suffer before reaching the consumer. Many difficulties are, deterioration of vital food compounds including flavour chemicals, lipids and vitamins through oxidation. The patent issued in 19th Century to coat meat with gelatin to delay microbial growth as loss of water was just the beginning. **(Havard and Harmony1869).**

Applications and Preparation of Edible Films

Edible films can provide either clear or milky(opaque) coatings to the product, but consumers generally prefer invisible, clear coatings. Coating can be obtained in various ways-

- By dipping the products into, or by brushing or spraying it with solution containing film Ingredients, so as to deposit the film directly on the food surface. **(Gontard and Guilbert 1994),** or
- By creating stand alone films from solution or through the formation for subsequent covering of food surface.

The simplest way to apply a film is directly from solution depending upon the concentration of coating solution, the product will absorb an appropriate amount of coating necessary to form the desired layer, which when dried forms a protective layer at the food surface. In most case, some plasticizers need to be added to coating solution to prevent the film becoming brittle. Possible food grade plasticizers are glycerol, mannitol, sorbitol, and sucrose because, if coating cracks, movement of various components will increased by orders of magnitude, resulting in mass flow instead of diffusion. Coatings should have a good adhesion to rough surface. **(Hershko et al 1996).**

Application of a uniform film or coating layer to cut fruits and vegetable surface is generally difficult. Better uniformity can be promoted by adding surfactants to the solution to reduce surface tension. This strategy will also reduce the superficial a_w, and in turn reduce water loss**(Roth 1984 and Loncin 1985).** In one standard process, Carboxymethylcellulose (CMC) powder was applied to cut fruits surfaces. The CMC adsorbed moisture within pores of the surface, causing CMC to swell which not only prevented moisture loss, but also provided a barrier against oxygen to prevent enzymatic discoloration **(DeLong and Shepherd 1972).** Coatings derived from non-aqueous media, such as applying an alcohol solution to shellac to candy, result in another level of complexity. For safety reasons the finished coating layer should not contain any solvent residue. Thus, during large scale operations, disposal of exhaust gases may present environmental challenges. In contrast when Zein films were obtained from solution after drying at 51°C for 10 mins, plasticizer was needed to obtain a non brittle material**(Kanig and Goodman 1962).** In contrast, drying at 35°C for 24 hours yielded a flexible Zein films without addition of plasticizer **(Guilbert 1986, 1988).** Films can also be formed by cooling concentrated solutions.

However the rate of cooling can again result in amorphous, crystalline, or polymorphism films with differing permeabilities. The characteristics of a polymorphism film may be further modified by tempering **(Landman et al. 1960; Kester and Fennema 1989).** Formation of flexible and stretchable films was also reported from molten acetylated monoglyceride **(Feuge et al. 1953).** Other possibilities are through precipitation, either by adding of selective miscible solvents that are not a solvent for the film component, or by desalting. In addition, some protein films can form upon heating causing unfolding of polymeric chains and the

replacement of intra molecular with inter molecular bonds. This transition effects permeability . In case of proteins, improved films can be obtained by adjusting coating solution pH in relation to the protein isoelectric point, where proteins become least soluble. However this process does not necessarily improve resistance of films to water transmission**(Krochta et al. 1988).** The pH can also adjusted by high pressure liquefied carbon dioxide treatment which although costly, does not leave any salt residue**(Tomasul et al. 1997).** When films comprised of pectin and alginate, are prepared by evaporation from water soluble components, they are subject to redissolution in water or destruction in high humidity conditions. This problem can be avoided by cross linking polymers at the film surface. Various reactions can be employed to achieve enhanced covalent bonding(e.g., treatment with formaldehyde); however such reactions can create new chemical structures that might necessitate approval by FDA. The most acceptable cross linking method involves ionic interaction between polymer chains via multivalent ions to form ionomers. While most synthetic films have higher tensile strength then typical edible films, ionomers are exception**(Pavlath et al. 1999a; Pavlath et al. 1999b).** For ionomers, tensile strength of their films is dependent on the number of available bonding locations. Ionomers cross linked films can be used as wrapping materials or, in case of water solubility, as bags that dissolve when immersed in water during food preparation(e.g., soup). In such cases, films do not have to be thin, because they will disappear before tasting and can further act as thickening agents within the food products. This aspect is especially important from an environmental perspective, where disposal is not necessary(becomes consumed as part of the food). Commercial synthetic materials are not generally biodegradable, while edible films typically are.

Thus, edible films provides an ideal solution for minimising packaging waste on-board ships during long voyages, during which maritime regulations forbid throwing of any refuse overboard. Edible films decompose readily providing an environmentally friendly solution.

Possible Components of Edible Films

The main components of our every day foods(e.g., proteins, carbohydrates and lipids) can fulfil requirements for preparation of edible films. As a general rule, fats are used to reduce water transmission; polysaccharides are used to control oxygen and transmission of other gases, while protein films provide mechanical stability. These materials can be utilised individually or as mixed composite blends to form films provided that they do not adversely alter food flavour. A major objective in preparing films for many foods(e.g., fresh fruits and vegetables) is to ensure that the generated films afford physical and chemical properties necessary to maintain transmission of various gases and liquids at the same rates as they occur within their native systems . Chemical structures of the three major components used to prepare films differ widely, and therefore attributes that each component contributes to overall film properties are different too.

Films from various sources of proteins, such as corn, milk, soy, wheat, and whey, have been used for years , their major advantage being their physical stability. It should be mentioned, however, that most of these protein sources are in fact mixtures of various proteins comprising a range of molecular weights. If they are used in solution rather than in emulsion, the solution will contain different protein fractions than the emulsion (unless all protein fractions are equally dissolved). Lower molecular weight components are generally more easily solubilized, though they exhibit higher permeabilities than higher molecular weight entities within films. While this limitation can be counteracted with cross linking, credibility and mouth feel of a film can be jeopardized by such treatment. While selecting protein for use in an edible film, consideration should extend beyond just protein functionality and GRAS status. It is important to recognise that a given segment of population is allergic to certain proteins, specifically to those of wheat. Consequently, collagen can be extruded to desired shapes such as a casing for sausage links. Collagen replaced traditional casing material (derived from animal intestines) because of its ease of manufacture and scale-up. In general, value of proteins as moisture barriers is low, and they also do not adequately control transfer of oxygen, carbon dioxide and other gases that are important to stability of various foods. Their major advantage is their structural stability, which makes it possible to hold a required form (e.g., sausage casing). Cross-linking can also occur in proteins where the isoelectric point is dependent on interaction of the amino and carboxylic groups of the protein. Thus depending on protein composition, permeability can also be altered. It was reported that depending on the pH of solution from which the film was cast, properties (e.g., colour, texture, tensile strength) were markedly different **(Gennadios et al.1993; Gontard et al. 1992)**. Water adsorption occurs readily at surface of polysaccharide films (e.g., those of alginate, carrageen, cellulose and its derivatives, dextrin, pectin and starch), because of the hydrophilic nature of most polysaccharides. Some polysaccharides such as cellulose derivatives, have lower water transmission than average polysaccharides, though they are still less effective than wax. The primary advantage of polysaccharides films are their structural stability and ability to slow down oxygen transmission. As a general rule films which do not provide protection against water transmission often have desirable properties in preventing oxygen transmission and vice versa **(Banker 1966).** Resistance to gas transmission can be so effective for polysaccharide films that it can be a challenge to manipulate. For example, permeability for oxygen in high amylose starch films was found to be virtually zero despite addition of plasticizers that were known to increase gas permeability **(Mark et al. 1966).** Therefore, in spite of their shortcomings with regard to water permeability, polysaccharides can be used to protect food from oxidation. Alginate coating can prevent lipid oxidation and stop rancidity**(Mate**

et al. 1996). An interesting role of polysaccharide films is to act as "a sacrificing agent" instead of as a barrier. Since most polysaccharides and other hydrophilic materials provide low protection against water transmission (i.e., they are highly hygroscopic), they may be applied as relatively thick films at food surfaces to intentionally absorb water and provide temporary protection against further moisture loss. Carrageenan, a sulfated polysaccharide of d-galactopyranosyl units was found to form a structured gel, which acted as sacrificing agent **(Glicksman 1982, 1983).** Alginate gels were also reported to possess this function **(Shaw et al. 1980).** Thus the coated product itself does not lose significant moisture until the sacrificing agent or film itself is dehydrated. If a surfactant is added to the coating, surface water activity can be altered without altering water content inside.

Waxes and fats are the oldest known edible film components. While most waxes are of natural origin, synthetic acetylated monoglyceride have similar characteristics and have been used with the blessing of the FDA in edible films for meat, fish and poultry. Originally, lipid coatings were applied by simply pouring molten paraffin or wax over citrus fruits. This process slowly gave way to adding a thin shiny layer by applying small amount of various waxes through dipping or spraying. The hydrophobic fruit surface, which also protects against abrasion during transportation, adds an aesthetic appearance. At the same time, thin wax coatings still allow some breathing to occur. They are excellent barriers to water transmission, while still slowing or altogether preventing other gas migration. Wax will affect oxygen and carbon dioxide transmission, and thus, can result in unwanted physiological processes, such as anaerobic respiration. This process in turn, will diminish quality of the product, resulting in softening of tissue structure, alteration of flavour, delay of ripening, and promotion of microbiological reactions **(Eaks et al. 1960).** In case of horticultural products with minimal respiration such as root vegetables, thick layers of wax are less harmful and can be used **(Hardenburg 1967).**

Application of edible films is especially difficult when applying lipophilic material to wet surfaces, such as cut fruits and vegetables. Direct application of any lipid to a hydrophilic or wet surface results in weak adhesion at the film-food interface. Dual-coating is one possible solution to this problem; as it provides protection against more than one permeate through use of different laminate layers. For example, the wet cut surface of an apple was first coated with alginate cross-linked via calcium ions. This initial coating provided a more appropriate foundation for subsequent hydrophobic coating with acetylated monoglyceride **(Wong et al. 1994a).** Unfortunately, two coating processes increase product cost and may also reduce commercial viability. Emulsions represent another approach to apply film, although it is still not clear whether emulsion-cast films are better than dual-coatings. Two conflicting reports, each claiming multiple fold advantages cite that emulsions are much better than dual- coatings **(Kamper and Fennema 1984)** and vice versa **(Martin-Polo et al. 1992, Debeaufort et al. 1994).** A more recent study forwards the general belief that multilayer films provide better protection than single layer films from emulsions **(Debeaufort et al. 1998).** From an economic point of view, emulsion-cast films have commercial appeal for several reasons. Use of a mixture of fat and carbohydrate components emulsified by protein, allows for direct adhesion of hydrophilic carbohydrate material at food surface and formation of a hydrophobic layer or coating at the external food surface. An aqueous emulsion containing 10% casein, 1% alginic acid and 15% of acetylated monoglyceride by weight resulted in a coating that reduced moisture losses for apple slices by 75% over a 3-day period – relative to uncoated slices. Effectiveness of this coating was unexpected, because alginic acid is hydrophilic and moisture losses should have been less if it were left out from the mixture. However, when the coating mixture did not contain either alginic acid or casein, there was only minimal decrease in water loss. It can be implied that casein provided a bridge between hydrophilic alginic acid and hydrophobic lipid, allowing adhesion to the hydrophilic cut surface **(Pavlath et al. 1993; Wong et al. 1994b).** However, there are several drawbacks to emulsion-type coatings. These coatings can be wet and difficult to handle and may function more as a sacrificial layer as opposed to a true moisture barrier. Emulsion stability is also sensitive to temperature and its efficiency can be affected by quality of emulsifier used. Such variations represent a handicap to commercial application.

Delivery of Food Additives and Antimicrobials using Edible Films and Coatings

Antimicrobials

The main cause of spoilage for many food products is surface microbial growth. Reduction of water activity (aw) and protection with moisture-proof packaging are common methods used to prevent spoilage in food products. Nevertheless, a reorganization of water inside the package, due to temperature changes, can induce condensation of moisture on the food surface, increasing the possibility for microbial growth **(Torres et al. 1985a, b).** Growth of yeasts, molds, and bacteria during product storage and distribution can drastically reduce food quality and food safety. Use of antimicrobials such as benzoic acid, sodium benzoate, sorbic acid, potassium sorbate, and/or propionic acid represents an additional means of food preservation. Edible coatings have been studied as antimicrobial carriers because of their effectiveness in retaining additives on food surfaces. Within the last decade, several groups have evaluated diffusivity of sorbic acid and potassium sorbate in model systems **(Guilbert 1988; Vodhani and Torres 1990; Torres and Karel 1985).** Early research studies applied antimicrobials and fungicides by dipping food in additive solution. This method was initially effective in reducing the total number of viable microorganisms, but on storage, preservative diffused into the food, allowing surface spoilage to occur. Application of fungicides in wax based emulsions or water suspension

has been studied on citrus fruit. The primary factor responsible for their effectiveness is dependent on method of application. The emulsified method was less effective of the two treatments, possibly due to encapsulation of the additive in the lipid phase **(Ecker and Kolbezen 1977).** Chitosan, as a matrix material for edible films and coatings, has been studied extensively. Chitosan films can prevent growth of *Listeria monocytogenes* **(Jeon et al. 2002)** and *Aspergillus niger* **(Shaw et al. 1980).** Chitosan used in combination with pectin improves mechanical properties of edible films **(Hoagland and Parris 1996).** Chitosan has been investigated as a dough ingredient in precooked pizza to protect against *Alternaria sp, Penicillium sp, Aspergillus sp* and *Cladosporium sp* **(Rodriguez et al. 2003).** When combined with hydroxypropyl methylcellulose on fresh strawberries, it can control Cladosporium sp and *Rhizopus sp* growth **(Park et al. 2005).** Interesting results have been obtained from enriched chitosan films with essential oils. These additives can protect skinless pink salmon fillets against *Listeria monocytogenes* **(Zivanovic et al. 2005),** while also preventing moisture loss and lipid oxidation **(Sathivel 2005).** Upon irradiation, chitosan coating on intermediate-moisture meat products had antioxidant and antimicrobial roles **(Rao et al. 2005).** When applied on cooked ground beef and turkey, it had a protective effect against *Clostridium perfringens* spores during chilling **(Juneja et al. 2006).**

Antioxidants

Antioxidants increase stability of food components, especially lipids, and maintain nutritional value and colour by preventing oxidative rancidity, degradation and discoloration. Acid or phenolic compounds act as antioxidants. Acid compounds, such as citric and ascorbic acid, are metal chelating agents. Phenolic compounds, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary butylated hydroxyquinone (TBHQ), propyl gallate and tocopherols inhibit lipid oxidation. These antioxidants can be incorporated into edible coatings, thus being retained on the food surface where they are most effective, since oxidation is a surface-air phenomenon. Edible coatings can also reduce enzymatic processes such as enzymatic oxidation **(Nisperos-Carriedo et al. 1990).**

Delivery of Flavour and Active Ingredients using Edible Films and Coatings

Edible films and coatings can deliver and maintain desirable concentrations of colour, flavour, spiciness, sweetness, saltiness, etc. Several commercial films, especially Japanese pullulan based films, are available in a variety of colours, with spices and seasonings included (Guilbert and Gontard 2005). Owing to its excellent oxygen barrier properties, pullulan films can be used to entrap flavours and colours and to stabilize other active ingredients within the film. Currently, the US Department of Agriculture's (USDA's) Agricultural Research Service (Albany, California), in cooperation with Origami Foods (Pleasanton, California), has developed vegetable and fruit edible films as alternatives to the seaweed sheets (nori) traditionally used for sushi and other Asian cuisine. These wraps, produced as soft and pliable sheets using infrared drying, can be made from broccoli, tomato, carrot, mango, apple, peach, pear, as well as a variety of other fruit and vegetable products. They can also be used to contain spices, seasonings, colorants, flavours, vitamins, and other beneficial plant-derived compounds. These food films are made commercially available by California-based Origami Foods and the USDA for use in a growing number of food applications, such as a bright orange, carrot-based wrap to encircle a cucumber, garlic, and rice filling; a deep red, tomato and basil-based wrap to hold a spicy tuna and rice filling; a blueberry or strawberry-based wrap to cover creamy cheesecake in mini desserts; a pineapple–apricot–ginger–based wrap to enclose rice and diced roast pork in elaboration of a sushi; and a broccoli-based wrap to encircle sushi of carrots, onions, and asparagus. Other uses might include snack crackers wrapped with fruit and vegetable films, apple wedges wrapped in peach film and tempura strawberry wrapped bananas. In a recent study, Laohakunjit and Kerdchoechuen (2007) coated non aromatic milled rice with 30% sorbitol–plasticized rice starch, containing 25% natural pandan leaf extract (*Pandanus amaryllifolius Roxb.*). This extract is primarily responsible for the jasmine aroma of aromatic rice. The rice starch coating containing natural pandan extract produced non aromatic rice with aroma compounds similar to that of aromatic rice. Additionally, coating treatment also reduced n -hexanal content of storage grains. This coating technique represents a promising approach for improving rice aroma and, at the same time, for reducing potential for oxidative rancidity during grain storage.

Edible Films and Coatings for Flavour Encapsulation

An important use of edible films is for encapsulation of flavourings. The edible film serves many purposes including permitting production of a dry, free-flowing flavour (most flavours are liquids), protection of flavourings from interaction with food or deleterious reactions such as oxidation, confinement during storage, and, finally, controlled release. The degree to which the edible film meets these requirements depends upon the process used to form the film around the flavouring and the film

composition itself. This chapter will discuss major processes used in manufacturing encapsulated flavourings, materials commonly used as the encapsulation matrix, and factors determining the efficacy of the edible film (hereafter termed the encapsulation matrix). Properties of the edible films used for the encapsulation of flavouring materials are critical to the efficacy of the flavouring material. The edible film must often serve as an emulsifier, film former (trap flavouring during the dehydration process), oxygen barrier (to protect against flavour deterioration) and controlled release agent. The materials available serve each of these functions to varying degrees. Maltodextrins are relatively inexpensive, but lack most of the functional properties desired in an encapsulation material. Corn syrup solids are also inexpensive and give excellent protection against oxidation. However, they also give poor retention during drying and no emulsification. Modified food starches are moderately priced excellent emulsifiers, and give excellent flavour retention during drying. These materials may give only limited protection to oxidation unless they are blended with other materials (e.g., mono- and disaccharides, Maltodextrins, or corn syrup solids). Gum acacias vary greatly in function properties. They generally are slightly more expensive than the modified food starches and somewhat inferior in emulsification properties and flavour retention. They offer excellent protection against oxidation, and therefore can be an excellent overall choice as an edible film for encapsulation of flavours. The gum acacias have the additional advantage of being "natural," which is important to some product labels. Proteins offer excellent emulsion stability and oxidative stability, but they are reactive with flavourings containing any carbonyls. Selection of these materials is dependent upon the process being used, the performance desired (emulsification or oxidation issues) and the controlled release properties desired in a finished application. There is no question that cost always enters the decision making process.

FUTURE TRENDS

The use of coatings and packaging films by the food industry has become a topic of great interest, because of their potential for increasing shelf life of many food products **(Ahvenainen2003; Coles et al. 2003; Giles and Bain 2001; Hernandez et al. 2000).** By selecting the right materials and packaging technologies, it is possible to maintain product quality and freshness of food products **(Brown 1992; Stewart et al. 2002).** Nowadays, a large part of materials used in packaging industries is produced from fossil fuels, which are practically not degradable. Preservation of natural resources and recycling has led to a renewed interest in biomaterials and renewable raw materials. A concerted effort to extend shelf life and to enhance food quality, while reducing packaging waste, has encouraged exploration of new bio-based packaging materials, such as edible and biodegradable films from renewable resources **(Albertsson and Karlsson 1995; Trznadel 1995; Tharanathan and Kittur 2003).** However, like conventional packaging, bio-based packaging has to supply a number of important functions with regards to food applications, including containment and protection, maintenance of sensory quality and safety, and labelling **(Robertson 1993).**

Probiotics are defined as live microbial food ingredients that have a beneficial effect on human health. The concept of Probiotics evolved from the hypothesis that the healthy life of Bulgarian peasants resulted from their consumption of fermented milk products **(Sanders 1999).** In the last century, probiotic bacteria most commonly studied include members of the genera *Lactobacillus* and *Bifidobacterium*. *Saccharomyces boulardii*, *Escherichia coli* and *Enterococcus* strains are used as probiotics in non-food formats. Some potential or established effects of probiotic bacteria have been reported **(Sanders and Huis in't Veld 1999)** such as an aid to lactose digestion, increased resistance to enteric pathogens, an immune system modulator, and as inhibition of anti-urogenital infections and hepatic encephalopathy. Increased worldwide interest in probiotics has set the stage for expanded marketing of these products. The benefit of probiotics as healthful ingredients could be enhanced if used in combination with other health-promoting dietary strategies **(Sanders 1999).** Microencapsulation and edible films and coatings have tremendous potential, because they are ideal delivery systems for a number of viable probiotics, either inside food products or on food surfaces. These techniques offer the possibility of controlling viable microorganism counts on an edible film, while simultaneously offering protection to changes in temperature, pH, chemical and enzymatic processes during food production, storage, consumption and digestion.

Development of new technologies to improve carrier properties of edible films and coatings is a major issue for future research. Currently, use of such edible films and coatings is limited. One of the main obstacles is cost, restricting their application to products of high value. Besides cost, other limiting factors for commercial use of edible films and coatings are lack of materials with desired functionalities, cost of investment for the installation of new film production or coating equipment, difficulty of the production process and strictness of regulations. In spite of these limitations, the food industry is looking for edible films and coatings that can be used on a broad spectrum of foods, add value to their products, increase product shelf life, and/or reduce packaging. However, more studies are yet necessary to develop new edible films and coatings containing active ingredients to understand interactions among components used in their production. When flavourings and active compounds (e.g., antimicrobials, antioxidants, and nutraceuticals) are added to edible films and coatings, mechanical properties can be dramatically affected. Studies addressing this subject are still very limited, and more information is needed to understand this behaviour.

There is little probability that new encapsulation processes will be introduced in the near future. Processes in use today reflect minor improvements in old methodologies as opposed to new or novel approaches. One might look to the pharmaceutical or

agrochemical fields for innovation, but constraints imposed by cost and legal use in the food industry generally make adoption of their methodologies not feasible. New materials are needed that meet our requirements from performance, cost, and legal use aspects.

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