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APPLICATION OF ACTIVE PACKAGING SYSTEMS IN PROBIOTIC FOODS

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ABSTRACT. Background: The packaging of the product has an important role in the protection of the stability of the final product. The use of active packaging system is due to play an increasingly important role by offering numerous and innovative solutions for extending the shelf-life or improve food quality and safety.

Methods: On the basis of broad review of the current state of the art in world literature, application of packaging systems in probiotics foods was discussed.

Results: In this study presented research and development in packaging systems for probiotics foods, using suitable materials with combine passive with active packaging solutions.

Conclusion: Active packages with incorporated oxygen barrier materials or films with selective permeability properties also have potential applications in the packaging of probiotic food products. This is a broad field of research for scientists and industry.

Key words: functional foods, probiotics, active packaging.

INTRODUCTION

Packaging has a significant role in the food supply chain and it is an integral part both of the food processes and the whole food supply chain. Food packaging has to perform several tasks as well as fulfilling many demands and requirements. Traditionally, a food package makes distribution easier. It has protected food from environmental conditions, such as light, oxygen, moisture, microbes, mechanical stresses and dust. Other basic tasks have been to ensure adequate labelling for providing information e.g., to the customer, and a proper convenience to the consumer, e.g., easy opening, reclosable lids and a suitable dosing mechanism. Besides, packaging has to satisfy all these various requirements effectively and economically. Some requirements and demands are contradictory to each other, at least to some extent [Ahvenainen, 2003]. In result, the demand for safe and high quality foods, as well as changes in consumer preferences have led to the development of innovative and novel approaches in food packaging technology [Puligundla et al., 2012]. Food industries uses a lot of packaging materials, and thus even a small reduction in the amount of materials and thus even a small reduction in the amount of materials used for each package would result in a significant cost reduction and may improve solid waste problems. Also, packaging technology has attempted to reduce the volume and weight of materials in efforts to minimize resources and costs. In result, innovations in packaging were up to now limited mainly to a small number of commodity materials such as barrier materials (new polymers, complex and multilayer materials) with new designs, for marketing purposes. Concept of active packaging system is due to play an increasingly important role by offering numerous and innovative solutions for

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extending the shelf-life or maintain, improve or monitor food quality and safety [Gontard, 2000].

DEFINITION OF PROBIOTICS

Consumers more and more believe that foods contribute directly to their health [Mollet & Rowland, 2002; Young, 2000]. Also, today foods are not intended to only satisfy hunger and to provide necessary nutrients for humans but also to prevent nutrition-related diseases and improve physical and mental well-being of the consumers [Menrad, 2003; Roberfroid, 2000]. Foods that affect specific functions or systems in the human body, providing health benefits beyond energy and nutrients-functional foods-have experienced rapid market growth in recent years. In response to the increasing numbers of consumers interested in maximizing their health, the food industry has developed an unprecedented variety of new functional food products [Granato et.al., 2010a]. According definition functional foods are those that contain one or more compound that provide important or limited functions in the organism, promoting welfare and health, or for reduction in the risk and protection of hypertension, diabetes, cancer, osteoporosis, and heart diseases [Arihara et.al., 2004]. Besides, functional foods present a potential to promote health through mechanisms not foreseen in conventional nutrition, with the need to be pointed out that these effects restrict them to the promotion of well-being and health by maximizing physiological functions of a person and not for the cure of illnesses [Sanders, 1998; Roberfroid, 2000]. These foods contain one or more beneficial compounds such as prebiotic, probiotic, antioxidant polyphenols and sterols, carotenoids, and others [Shah, 2001; Andlauer and Fűrst, 2002; Granato et.al., 2010b].

Table 1. Lists some of health benefits of consuming probiotics
Tabela 1. Lista wybranych zalet zdrowotnych spożywania probiotyków

Intestinal effects	– relieve effects, promote recovery from diarrhea (rotavirus, travelers' and antibiotic induced) – produce lactase, alleviate symptoms of lactose intolerance and malabsorption – relieve constipation – treat colitis
Immune system effects	– enhance specific and nonspecific immune response – inhibit pathogen growth and translocation – stimulate gastrointestinal immunity – reduce chance of infection from common pathogens (Salmonella, Shigella)
Other effects	– reduce risk of certain cancers (colon, bladder) – detoxify carcinogens – suppress tumors – lower serum cholesterol concentrations – reduce blood pressure in hypertensives – treat food allergies – synthesize nutrients (folic acid, niacin, riboflavin, vitamins B6 & B12) – increase nutrient bioavailability – improve urogenital health – optimize effects of vaccines (e.g. rotavirus vaccine, typhoid fever vaccine)

Source: Dairy Council of California, 2000.

Probiotics are defined as "live microorganisms, as they are consumed in adequate numbers confer a health benefit on the host", with ongoing controversy as to whether cultures must be viable for efficacy in all cases [Charalampopoulos et. al., 2003; Charalampopoulos et.al., 2002; Stanton et al., 2005]. Saxelin and others, [2003] defined probiotic food as a processed product that contains viable probiotic microorganisms in a suitable matrix and in sufficient concentration. Table 1 lists some of health benefits of consuming probiotics.

In order to exert health benefits beyond inherent basic nutrition, it is necessary that the activity of the probiotic culture be maintained at sufficiently high levels throughout the shelf-life of the product. This requires optimization of all phases of the manufacturing process, including the selection of adequate materials to be incorporated into the packaging of the finished food product [Cruz et.al., 2007]. Also, role of packaging systems for functional and probiotic foods is very important.

ACTIVE PACKAGING SYSTEMS

In contrast to traditional packaging, active packaging may change the composition and organoleptic characteristics of food, provided that the changes are consistent with the provisions for food. Besides, the released substances will be allowed to add to food. The principles behind active packaging are based either on the intrinsic properties of the polymer used as packaging material itself or on the introduction [inclusion, entrapment etc.] of specific substances inside the polymer [Gontard, 2000]. Active packaging refers to the incorporation of certain additives into packaging systems (whether loose within the pack, attached to the inside of packaging materials or incorporated within the packaging materials themselves) with the aim of maintaining or extending product quality and shelf-life [Hutton, 2003]. Active packaging was developed to meet high requirements of consumers, connected among other things with an extension of shelf life of products, improvement of its organoleptic attributes and protection. In order to be able to satisfy these requirements active packaging contains several specific additives [Bilska, 2011]. Antimicrobial packaging is a form of active packaging. These types of packaging acts to reduce, inhibit or retard the growth of microorganisms that may be present in the packed food or packaging material itself [Appendini and Hotchkiss, 2002].

According to Cooksey [2001] active packaging systems aimed at quality improvement and shelf-life extension of foods can be categorized by three concepts, firstly direct incorporation of active substances into the packaging film, secondly edible films and coating with bioactive substances, and thirdly incorporation of the active substances into a sachet, patch or tablet. Most common and promising are antimicrobial packaging systems,O2 scavenging systems, and moisture-control systems, which offer significant benefits to the meat industry and consumers, and for which exist a large potential market [Han & Floros, 2007]. Also, active food packaging plays a dynamic role in food preservation and allows packages to interact with food and the environment. These packaging technique enables the regulation of various aspects that may play a role in determining the shelf life of packaged foods, such as physiological (e.g., respiration of fresh fruit and vegetables), chemical (e.g., lipid oxidation), and physical (e.g., dehydration) processes as well as microbiological aspects [Puligundla et al., 2012].

Active packaging techniques can be divided into three categories; absorbers (i.e. scavengers), releasing systems and other systems. Absorbing (scavenging) systems remove undesired compounds such as oxygen, carbon dioxide, ethylene, excessive water, taints and other specific compounds Releasing systems actively add or emit compounds to the packaged food or into the head-space of the package such as carbon dioxide, antioxidants and preservatives. Other systems may have miscellaneous tasks, such as self-heating, self-cooling and preservation. Depending on the physical form of active packaging systems, absorbers and releasers can be a sachet, label or film type. Sachets are placed freely in the head-space of the package. Labels are attached into the lid of the package. Direct contact with food should be avoided because it impairs the function of the system and, on the other hand, may cause migration problems [Ahvenainen, 2003].

Oxygen absorbing technology is based on oxidation or combination of one of the following components: iron powder, ascorbic acid, photosensitive polymers, enzymes, etc. [Cruz et al., 2007]. An appropriate oxygen scavenger is chosen depending on the O_2-level in the headspace, how much oxygen is trapped in the food initially and the amount of oxygen that will be transported from the surrounding air into the package during storage. The nature of the food (e.g. size, shape, weight), water activity and desired shelf-life are also important factors influencing the choice of oxygen absorbents [Vermeiren et al., 2003]. Oxygen scavengers must satisfy several requirements such as to be harmless to the human body, to absorb oxygen at an appropriate rate, to not produce toxic substances or unfavorable gas or odor, to be compact in size and are expected to show a constant quality and performance, to absorb a large amount of oxygen and to be economically priced [Nakamura and Hoshino, 1983; Abe, 1994; Rooney, 1995]. At present, suitable materials combine passive with active barrier layers, e.g. oxygen consuming layers or oxygen scavengers are known.

Another popular group of active packaging systems are moisture absorbers. Several companies manufacture moisture absorbers in the form of sachets, pads, sheets or blankets. For packaged dried food applications, desiccants such as silica gel, calcium oxide and activated clays and minerals are typically tear-resistant permeable plastic sachets. In addition to moisture-absorber sachets for humidity control in packaged dried foods, several companies manufacture moisture-drip absorbent pads, sheets and blankets for liquid water control in high raw foods such as meats, fish, poultry, fruit and vegetables. Basically, they consist of two layers of a microporous non-woven plastic film, such as polyethylene or polypropylene, between which is placed a superabsorbent polymer which is capable of absorbing up to 500 times its own weight with water [Rooney, 1995]. Interesting solution in scavengers is use a carbon dioxide scavenger or a dual-action oxygen and carbon dioxide scavenger system. A mixture of calcium oxide and activated charcoal has been used in polyethylene coffee pouches to scavenge carbon dioxide but dual-action oxygen and carbon dioxide scavenger sachets and labels are more common and are commercially used for canned and foil pouched coffees in Japan and the USA [Day, 1989; Anon, 1995; Rooney, 1995]. Ethanol emitters are a sub-set of preservative releasing technologies although ethanol emitters are usually in sachet forms as opposed to impregnated preservative releasing films. The use of ethanol as an antimicrobial agent is well documented. It is particularly effective against mould but can also inhibit the growth of yeasts and bacteria. Several reports have demonstrated that the mould-free shelf-life of bakery products can be significantly extended after spraying with 95% ethanol to give concentrations of 0.5-1.5% (w/w) in the products. However, a more practical and safer method of generating ethanol is through the use of ethanol emitting sachets [Rooney, 1995; Labuza and Breene, 1989; Day, 2003].

PACKAGING SYSTEMS FOR PROBIOTIC FOODS

The oxygen level throughout storage of the product should be as low as possible to avoid toxicity and death of the microorganism and consequent loss of functionality of the product. Mattila-Sandholm et al., [2002] reported that the packaging materials used and the storage conditions are important factors for the quality of products containing probiotic microorganisms because the metabolism of this microbial group is essentially anaerobic or microaerophilic. Also, many studies in search of material for probiotics packaging.

Ishibashi and Shimamura in 1993, reported that packaging materials such as polyethylene and polystyrene are gas permeable and allow the diffusion of oxygen into yoghurt during storage. Packaging probiotic yoghurts in glass bottles has been reported to prevent oxygen diffusion and therefore result in significantly higher number of probiotic bacteria [Dave & Shah, 1997a], it suffers from some drawbacks. However, glass bottles are costly as well as hazardous and therefore this option may not be financially viable for all yoghurt manufacturers.

Cruz et.al. [2012] studied stability of probiotic stirred yogurt added with glucose oxidase in different packaging materials along the refrigerated storage. Probiotics yogurts added with glucose oxidase and packaged in different plastic packaging systems [monolayer polypropylene (PP) or PP coextruded with ethylene vinyl alcohol (EVOH) cups (100 ml) that present different oxygen permeability transfer rates (0.09, 0.2, 0.39 and 0.75 mL O_2/day) was evaluated during 28 days of refrigerated storage. The results suggested that the use of packaging systems with different oxygen permeability rates coupled with the addition of glucose oxidase presented an interesting technological option to minimize the oxidative stress in yogurts, once these conditions were able to maintain low levels of dissolved oxygen and also to maintain the cell viability of B. longum and L. acidophilus, mainly up to the 21st day of storage. Kudełka in 2005, analyzed the effect of pasteurization and package type (of polypropylene, polystyrene and polyethylene, as well as in glass containers) on the acidity of probiotic yogurts made from goat's and cow's milk during 21 days refrigerated storage. In result, throughout the storage period studied, the yogurt with lowest acidity values was that contained in polystyrene packages as compared to the other package types evaluated, which all exhibited similar values for this parameter.

Senaka and others, [2013], studied the viability of L. acidophilus LA- 5, B. animalis subsp. lactis BB-12 and the novel probiotic P. jensenii 702 in ice cream made from goat's milk. They evaluated the physico-chemical and sensory properties during stored products in different packaging materials: polypropylene, polyethylene and glass. Packaging materials had a significant influence on the complete melting time of ice cream, and with the melting quality of the product as identified by the tasting panel, one week after production. The influence of packaging was not apparent in relation to other physicochemical properties and sensory attributes of the product, while variation in certain sensory properties such as body and texture and taste of the product was apparent after 12 weeks storage.

ACTIVE PACKAGING IN PROBIOTIC FOODS

The oxygen permeability of the packaging material used currently for probiotic yoghurts is considered a key factor in the high levels of oxygen present in yoghurt. Few current packaging techniques are capable of preventing oxygen permeation. Additional alternatives to traditional packaging probiotics include the addition of oxygen absorbers or scavengers. Active packages with incorporated oxygen barrier materials or films with selective permeability properties also have potential applications in the packaging of probiotic food products [Cruz et al., 2007]. Oxygen toxicity is considered a significant factor influencing the viability of probiotic bacteria in yoghurts [Klaver et al., 1993; Dave & Shah, 1997a-c]. While L. acidophilus is microaerophilic, bifidobacteria are categorized as strict anaerobes. Exposure to oxygen can therefore result in the intracellular accumulation of toxic oxygenic metabolites in these bacteria, leading to a loss in viability [Condon, 1987]. Alternative to HIPS such as the polystyrene-based gas barrier NupakTM [Visypac, Melbourne, Australia] has been shown to be effective in preventing diffusion of oxygen into yoghurts during storage [Miller et al., 2002]. Active packaging film, ZeroTM 2 [CSIRO, Sydney, Australia] that can actively scavenge oxygen from the product has also been developed. Dave & Shah [1997b,c] used oxygen scavengers such as ascorbate or cysteine in yoghurts to protect L. acidophilus and Bifidobacterium spp. from oxygen toxicity. They observed reduction in the oxygen content and redox potential of yoghurt, together with an improvement in the counts of L. acidophilus and Bifidobacterium spp., the incorporation of ascorbic acid in yoghurts can however reduce the amount of oxygen required for the activities of S. thermophilus, an aerobic organism used as a starter culture in the manufacture of yoghurt. This can have a detrimental effect on the textural and nutritional qualities of yoghurt and this technique may hence be undesirable in the industrial manufacture of yoghurt

Talwalkar et.al. [2004], studied effects of packaging materials on the dissolved oxygen and the survival of the probiotic bacteria in yoghurt. Oxygen adapted and non-oxygen adapted strains of Lactobacillus acidophilus and Bifidobacterium spp. were incorporated in yoghurts, which were packaged in oxygen permeable high-impact polystyrene [HIPS], oxygen-barrier material [NupakTM] and NupakTM with an oxygen scavenging film [Zero2 TM]. The studies showed packaging materials such as NupakTM and ZeroTM 2 can serve as cheaper and practical packaging for products in which it is necessary to prevent oxygen diffusion or scavenge any residual oxygen. Miller et. al. [2002] researched of dissolved oxygen content in probiotic yoghurts by alternative packaging materials. They compared high-impact polystyrene with new oxygen-barrier material and an oxygen-scavenging active packaging system. They observed stirred-type and set-type yoghurts in each packaging material for dissolved oxygen content, over a normal shelf-life for yoghurt. In result, oxygen-barrier packaging combined with an oxygen scavenging material was found to be the most effective system, particularly when used with set-type yoghurt. Besides, set-type yoghurt was found to be more conducive to oxygen reduction using packaging methods.

Viable cell counts of S. thermophilus and B. bifidum in fermented soy milk filled into glass packages, polyethylene packages containing an oxygen absorber and a desiccant, and a laminated bag (nylon/aluminum/ polypropylene) was monitored by Wang et.al., [2004]. The product stored at 25°C exhibited higher values compared to the product kept at 4°C, with the differences being directly proportional to the temperature difference. The higher the permeability of the packaging material means the lower the number of viable bacterial cells. Hisiao et.al. [2004] studied the effect of the packaging material and the storage temperature on the viability of microencapsulated bifidobacteria. The samples in the different packages with oxygen absorbres were stored at 4 and 25°C. Using of an oxygen absorber and desiccant improved the viable cell counts, particularly at 25°C.

SUMMARY

Food package helps protect food from environmental influences, such as moisture, light, oxygen, microbes, mechanical stresses and dust. These factors lead to or enhance the deterioration of food or drink. The use of appropriate packaging materials and systems is of utmost importance to safeguard the improvements introduced in the manufacturing process as a whole and ensure that the product lives up to the expectations of the people that consume these products. An ideal food packaging material should be inert, not to allow the transfer, i.e. must have a perfect barrier property, and recyclable. Food package makes distribution easier. Apart from these, there are other important functions of packaging, including containment, convenience, marketing, and communication. The use of active packaging for this type of functional food is a broad field of research for scientists and industry. Also, active packages with incorporated oxygen barrier materials or films with selective permeability properties also have potential applications in the packaging of probiotic food products.

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ZASTOSOWANIE AKTYWNYCH SYSTEMÓW PAKOWANIA DO ŻYWNOŚCI PROBIOTYCZNEJ

STRESZCZENIE. **Wstęp:** Opakowanie pełni istotną rolę w ochronie produktu końcowego. Zastosowanie aktywnego systemu pakowania odgrywa coraz istotniejszą rolę poprzez oferowanie licznych i nowatorskich rozwiązań w celu przedłużenia okresu ważności produktu, czy też poprzez poprawę jego jakości i bezpieczeństwa.
Metody: Na podstawie szerokiego przeglądu aktualnego stanu badań w literaturze światowej, omówiono systemy pakowania żywności probiotycznej.
Rezultaty: W pracy zaprezentowano prowadzone badania w zakresie systemów pakowania dla żywności probiotycznej, szczególnie przy zastosowaniu odpowiednich połączeń materiałów pasywnych z materiałami aktywnymi.
Wnioski: Aktywne opakowania połączone z materiałami o określonej barierowości czy foliami o określonej przenikalności, mają potencjalne zastosowanie w pakowaniu żywności probiotycznej i stanowią szerokie pole do badań zarówno dla naukowców jak i przemysłu.

Słowa kluczowe: żywność funkcjonalna, probiotyki, opakowania aktywne.

ANWENDUNG VON AKTIVEN VERPACKUNGSSYSTEMEN FÜR PROBIOTISCHE LEBENSMITTEL

ZUSAMMENFASSUNG. Einleitung: Die Verpackung spielt eine wichtige Rolle beim Schutz des Endproduktes. Die Verwendung von aktiven Verpackungssystemen gewinnt zunehmend an Bedeutung, indem zahlreiche und innovative Lösungen eingeführt werden, um durch die Verbesserung der Qualität und Sicherheit die Gültigkeit des Produktes zu verlängern.

Methoden: Basierend auf einem breiten Überblick über den aktuellen Stand der Forschung in der Fachliteratur der Welt, wurden Verpackungssysteme für probiotische Lebensmittel durchdiskutiert.

Ergebnisse: Dieser Beitrag stellt laufende Forschungen im Bereich der Verpackungssysteme für probiotische Lebensmittel dar, vor allem unter Anwendung geeigneter Kombinationen von passiven und aktiven Materialien.

Fazit: Aktive Verpackungen mit einer bestimmten Permeabilität von Materialien oder Filmen kombiniert, haben ihren möglichen Einsatz in der Anwendung von Lebensmittelverpackungen gefunden und sind somit im Falle der probiotischen Lebensmittel ein breites Feld für die Forschung und eine entsprechende Industrieentwicklung geworden.

Codewörter: funktionelle Lebensmittel, Probiotika, "aktive Verpackung".

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