Assessing Safety of Food Packaging Materials

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Abstract

Packaging today plays an important role in the quality of food products by providing protection from environmental, chemical, and physical challenges. Food packaging is essential and pervasive: essential because without packaging the safety and quality of food would be compromised, and pervasive because almost all food is packaged in some way. Food packaging performs a number of disparate tasks: it protects the food from contamination and spoilage; it makes it easier to transport and store foods; and it provides uniform measurement of contents. By allowing brands to be created and standardized, it makes advertising meaningful and large-scale distribution and mass merchandising possible. Food packages with dispensing caps, sprays, reclosable openings, and other features make products more usable and convenient. This principal function of packaging involves retardation of deterioration, extension of shelf-life, and maintenance of quality and safety of packaged food. Consumer awareness of food safety and nutrition is a major issue in relation to healthy lifestyles and disease prevention. Improper consumer food management has been implicated in a large number of cases of foodborne illnesses. The right selection of packaging materials and technologies maintains product quality and freshness during distribution and storage.

Keywords: food safety, packaging material, migration, antimicrobial.

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Introduction

In industrialised countries, where the problem of food security is generally absent, health problems related to food refer to two main factors: food safety and nutritional risks. Considering together these “food related” pathologies, the burden of disease in western countries is impressive (16) Packaging today plays an important role in the quality of food products by providing protection from environmental, chemical, and physical challenges. This protection can be as simple as preventing breakage of the product to providing barriers to moisture, oxygen, carbon dioxide, and other gases as well as flavors and aromas. The principal roles of food packaging are to protect food products from outside influences and damage, to contain the food, and to provide consumers with ingredient and nutritional information (7). Packaging can block light to protect nutrients and colors in a product from deteriorating. In addition to providing passive protection, many packages today play an active role in the quality of a product by helping to maintain a desired atmosphere around the product. packaging materials have the three primary functions of providing protection, utility, and communication in three different environments. Four primary and interconnected functions of packaging have been identified: containment, protection, convenience, and communication (31). Traceability, convenience, and tamper indication are secondary functions of increasing importance. The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact.

The benefits of processing and packaging

The quality of the packaged food is directly related to the food and packaging material attributes (9,22). Most food products deteriorate in quality due to mass transfer phenomena, such as moisture absorption, oxygen invasion, flavour loss, undesirable odour absorption, and the migration of packaging components into the food (19,34). The phenomena can occur between the food product and the atmospheric environment, between the food and the packaging materials, or among the heterogeneous ingredients in the food product itself. Thus, the rate of transport of such reactants across the partial barrier of the package wall can become the limiting factor in shelf life (13,18).

Materials Used in Food Packaging

Package design and construction play a significant role in determining the shelf life of a food product. The right selection of packaging materials and technologies maintains product quality and freshness during distribution and storage. Materials that have traditionally been used in food packaging include glass, metals (aluminum, foils and laminates, tinplate, and tin-free steel), paper and paperboards, and plastics. Moreover, a wider variety of plastics have been introduced in both rigid and flexible forms. Today's food packages often combine several materials to exploit each material's functional or aesthetic properties. As research to improve food packaging continues, advances in the field may affect the environmental impact of packaging(24). Many packages are still simply containers, but they have properties that have been developed to protect the food. These include barriers to oxygen, moisture, and flavors. Active packaging, or that which plays an active role in food quality, includes some microwave packaging as well as packaging that has absorbers built in to remove oxygen from the atmosphere surrounding the product or to provide antimicrobials to the surface of the food. Packaging has allowed access to many foods year-round that otherwise could not be preserved. It is interesting to note that some packages have actually allowed the creation of new categories in the supermarket. Examples include microwave popcorn and fresh-cut produce, which owe their existence to the unique packaging that has been developed(30). Materials that provide optimum protection of product quality and safety are most preferred. Similarly, distribution systems and conditions help determine the type of packaging material used. Ideally, a food package would consist of materials that maintain the quality and safety of the food indefinitely with no degradation over time; are attractive, convenient, and easy to use while conveying all pertinent information; are made from renewable resources, generating no waste for disposal; and are inexpensive. Rarely, if ever, do today's food packages meet this lofty goal. Creating a food package is as much art as science, trying to achieve the best overall result without falling below acceptable standards in any single category(24). Table 1 provides an overview of the variety of factors at play in package selection.

Safety evaluation of Food packaging materials

Premarket approval by FDA is currently required for food packaging materials used in the US that are not GRAS (Generally Recognized As Safe), prior sanctioned, or not reasonably expected to become a component of food. These components or food additives must be shown through the food additive petition process to be safe for their intended use. In some food packaging applications, the amount of migration could be considered so small as to be negligible and therefore present no public health or safety concern. In an effort to improve and speed the food additive petition process, FDA has adopted a threshold policy that defines this negligible exposure from migration. For many packaging components, the amount of migration data available today and the ability to predict the diffusion coefficient of an additive/contaminant in the polymer make it possible to estimate the amounts of chemicals migrating from food packaging without the need for additional migration testing(4).

Table 1- Properties, Environmental Issues, and cost for packaging materials(24).

Material	Product characteristics/food compatibility		Consumer/Marketing Issues		Environmental Issues		Cost
	Advantages	Disadvantage	Advantages	Disadvantage	Advantages	Disadvantage	
Glass	Impermeable to moisture and gases Nonreactive (inert) Withstands heat processing	Brittle and Breakable Needs a Separate closure	Transparent, allows consumer to see product Can be colored for light sensitive products	Poor portability: heavy and breakable Relatively difficult to decorate	Reusable Recyclable Often Contains recycled content	Heavy and bulky to transport	Low cost material but somewhat costly to transport
Aluminum	Impermeable to moisture and gases Resistant to corrosion Withstands heat processing	Cannot be welded Limited structural strength	Easy to decorate Lightweight Good portability, Lightweight and not breakable	Limited shaped	Recyclable Lightweight Economic incentive to Recycle	No disadvantage in rigid form Separation difficulties in laminated form	Relatively expensive but calue encourages recycling
Tinplate	Impermeable Strong and formable Resistant to corrosion Withstands heat processing	Can react with foods; coating required	Easy to decorate	Typically requires a can opener to access product	Recyclable Magnetic thus easily separated	Heavier than aluminum	Cheaper than alminum
Tin-free steel	Strong Good resistance to corrosion Withstands heat processing	Difficult to weld, requires removal of coating Less resistant to corrosion	Easy to decorate	Typically requires a can opener to access product	Recyclable Magnetic thus easily separated	Heavier than aluminum	Cheaper than tinplate

Table 1. Continued							
Material	**Product characteristics/food compatibility**		**Consumer/Marketing Issues**		**Environmental Issues**		**Cost**
	Advantages	**Disadvantage**	**Advantages**	**Disadvantage**	**Advantages**	**Disadvantage**	
Polyolefins	Good moisture barrier Strong Resistant to chemical	Poor gas barriers	Lightweight	Slight haze or translucency	Recyclable High energy source for incineration	Easily recycled in semi-rigid form but identification and separation more difficult for films	Low cost
Polyesters	Strong Withstands hot filling Good barrier properties		High clarity Shatter resistant		Recyclable	Easily recycled in rigid form but identification and separation more difficult for films	Inexpensive but higher cost among plastics
Polyvinyl chloride	Moldable Resistant to chemical		High calrity		recyclable	Contains chlorine Requires separating from other waste	inexpensive
Polyvinylidene chloride	High barrier to moisture and gases Heat sealable Withstands hot filling		Maintains product quality		recyclable	Contains chlorine Requies separating from other waste	Inexpensive but higher cost among plastic
Polystyrence	Available in rigid, film, and foam form	Poor barrier properties	Good quality		Recyclable	Requires separating from other waste	inexpensive
Polyamide	Strong Good barrier properties				Recyclable	Requires separating from other waste	Inexpensive but higher cost among plastics
Ethylene vinyl alcohol	High barrier to gases and oils/fat	Low moisture barrier/moisture sensetive	Maintains product quality for oxygen-sensetive products		Recyclable	Requires separating from other waste	Inexpensive when used as thin film
PLA	Biodegradable hydrolysable				Recyclable	Requires separating from other waste	Relativerly expensive
Paper & Paperboard	Very good strength to weight characteristics	Poor barrier to light Recycled content makes it unsuitable for food contact material	Low-density materials Efficient, low cost protection Easily decorated	Moisture sensitive, loses strength with increasing humidity Tears easily	Made from renewable resources recyclable		Low cost
Laminates/co-extrusions	Properties can be tailored for product needs		Flexibility in design and characteristics		Often allows for source reduction	Layer separation is required	Relatively expensive but cost effective for purpose

Migration from food-packaging materials

Food-packaging materials must be safe in the sense of not releasing potentially harmful material into the food. Safety might never be complete, but should be brought to the standards achievable at the given time. Migrants present in the foods at a concentration of potential toxicological concern should be known and documented to be of no risk to human health. Every day we consume foods that have been in contact with many different types of packing materials and regularly ingest hundreds of migrants. Legislation must make sure that not one of these is seriously toxic. It is one of the most challenging tasks of food control to make sure that the presence of any potentially toxic migrants would be detected(14).

Food contamination can result from various interactions Between food and packaging materials. Migration of volatiles, additives, monomers and oligomers from packaging materials into food or adsorption of volatile compounds from the food by the polymer are important considerations from safety, hygienic and economic points of view. The term 'migration' includes two phenomena (partition and diffusion) that can be important in determining the concentration of contaminants in a food system at any time. An estimation of the partition coefficient, K, in food/packaging systems has been the major objective of numerous different studies. Various parameters can influence K such as temperature, pH, the chemical structure of the migrant, molecular size and structure, fat content, and degrees of crystallinity. Some theoretical approaches such as the quantitative structure–property relationship method could be of interest in the near future(41).

There are various methods for determining migration into foods. Unlike most food additives, these exposures typically are very small. Because of this, and since complete toxicological data sets are not always available for packaging materials, the US Food and Drug Administration (FDA) has developed a process to make the evaluation of packaging materials more efficient, instead of the extensive review normally required for food additives. This process is used to determine `when the likelihood or extent of migration to food of a substance used in a food contact article is so trivial as not to require regulation of the substance as a food additive'. This trivial level, also known as the threshold of regulation, was based upon a large database of carcinogenic potencies and was determined to be 1.5 µg/person day^{-1}. This was determined to `be low enough to ensure that the public health is protected, even in the event that a substance exempted from regulation as a food additive is later found to be a carcinogen' . Substances not having structural alerts, or that are not known carcinogens or potent toxins, based on existing toxicological information, and are below the threshold value, are considered by the FDA to be exempted from regulation as food additives. The threshold of regulation approach used by the FDA provides an excellent model by which to evaluate the majority of packaging materials(28).

Risk Assessment of Plastic Food Containers

In the manufacture of plastic containers, various materials such as additives (for example, plasticizers,stabilizers, antioxidants), polymers (for example, polystyrene [PS], polycarbonate [PC], polyvinyl chloride [PVC]) are widely used. Endocrine disrupting chemicals [EDCs] can migrate as residual monomers (for example, styrene for PS or bisphenol A [BPA] for PC) presented in polymers, as additives (for example, phthalates for PVC) used in polymer manufacturing, and/or as contaminants from the polymers depending on physicochemical conditions such as temperature, UV light, pH, microwave, and mechanical stress. Most of these plastics contain additional chemicals to bestow properties such as flame resistance, color, flexibility, and softness.

Food risk hazards: raw materials and processes

Before discussing different food safety issues we should introduce the meaning of the following terms: a hazard is a potential source of danger; a risk is a measure of the probability and severity of harm to human health; safety is a judgment of the acceptability of risk. A substance in food is considered safe if its risks are judged to be acceptable. A perception of relative risk of food hazards by different socio-professional groups is not the same; according to scientists the most important are food-borne diseases, followed by nutrition imbalance, natural toxicants, environmental contamination, pesticide residues, veterinary drug residues, and additives. safe if its risks are judged to be acceptable(35).

Hazards of packaging materials in contact with foods

The substances that may migrate and that may affect the safety of the food obviously depend on the nature of the packaging material. The constant introduction of novel packaging materials has increased the number of specific hazards to which humans are exposed via the migration from packaging into food. Synthetic polymers typically have high molecular weights (5000-1 million D) and therefore their biological availability is negligible. However, due to the use of lower molecular weight (<1000D) additives in these polymers as well as the presence of trace levels of unreacted monomers, there is a finite potential for human exposure to these lower molecular weight components. Substances that may migrate from plastic materials include monomers and starting substances, catalysts, solvents and additives. This latter class includes antioxidants, antistatics, antifogging agents, slip additives, plasticizers, heat stabilisers, dyes and pigments(**2**).

Paper and board

Paper and board are essentially composed of pulp from different vegetable sources and are most often employed in contact with dry foods. Additives used in this type of material include fillers, starch and derivatives, wet strength sizing agents, retention aids, biocides, fluorescent whitening agents and grease-proofing agents. Paper and board may also be coated with polymers as polyethylene or waxes. Recycled fibre is considered a major source of migrants.

1.1.1. Metal cans

Metal cans are made of tin-plate (steel coated with tin), tin-free steel (steel coated with chromium and chromium oxides) or aluminium. Tin-plate is most used for food cans and aluminium for beverage cans. Most cans are internally coated with a polymeric layer, and thus the layer of food contact is not the metal but the lacquer. The substances of concern in can systems are therefore not only the metals involved, but also components migrating from the coatings, such as starting substances and their potential derivatives. Migrants from can coatings, namely phenolic resins, often contain only small amounts of monomers, oligomers and additives, but a large amount of other unknown or undescribed components(14).

Glass packaging

Glass Packaging has as its major components, silica, sodium and calcium oxides. These components are unlikely to have any significant effect on the safety of foods since they are natural constituents of many foods. Silica is also the major component of food-contact ceramics. Clays, another major raw material of ceramics, is composed of alumina, silica and water. Substances of concern may, however, originate from glazes and printing inks. Thus lead and cadmium are frequently controlled in such materials since they may be present as contaminants. The Food Standards Agency (UK) promoted a comprehensive overview of the potential for elemental migration from different glass types used in food-contact applications in a range of conditions of use. As can been seen, there is a great variety of chemicals involved and an often complex mixture of migrants.

Effect of packaging on food safety

Food packaging

Well adapted packaging keeps the food integrity, insures its safety in terms of microbiological and other contamination, and pollution. The enzymatic reactions can be retarded thanks to 'sous vide ' conditioning. However, the problem of migration has to be considered. The French expression 'migration contenant-contenu', or simply micro-migration of packaging materials into food, the use of susceptors in microwave ovens create the possibility of migration of plasticizers into the food either because of a long period time of contact (monomer migration) or because of a local high temperature (plastisizer migration from susceptors into the food). The procedure of toxicological evaluation linked with migration of materials in contact with food are rigorous; several examinations are required such as mutagenicity study, bioaccumulation tests, 90-day toxicity study, reproductive and teratogenic effects, toxicokinetics and metabolism and a long-term carcinogenesis investigation. This battery of tests could be completed with those on immune function effects(35).

Packaging and environment

The problems of packaging and environment are extremely important. Amounts of waste increase and the possibility of treatment is limited. National and international commissions are currently working to find solutions to these problems. Packaging, on the one hand, allows a reduction in the amount of wastes, but also contributes to the 'visual pollution' and damage to the environment. reduce the weight of materials used for packaging. Some types of packaging such as glass or plastic bottles can be used for recycling. For the majority of very light packaging that are in direct contact with fats or oils, the energetic valorisation has to be considered and the precise 'ecobilan' data are currently under way in several European countries(**35**).

Risk Assessment of Packaging Material

Key component s of the risk assessment of packaging materials

The US Food and Drug Administration (FDA) includes packaging materials in its defnition of a food contact substance. A food-contact substance is specified as any substance that is intended for use as a component of materials used in manufacturing, packing, packaging, transporting, or holding food if the use is not intended to have any technical effect in the food(**3**). The FDA further identifies any food-contact substance that is reasonably expected to migrate to food under conditions of intended use to be a food additive. Human exposure to packaging materials could therefore occur through the potential migration of packaging material substances to food. It is the extent of migration, in addition to the inherent toxicity of the packaging material component(s), that comprises the parameters of risk assessment of packaging materials(28).

Considerations for Use of Different Packaging Materials

The key to successful packaging is to select the package material and design that best satisfy competing needs with regard to product characteristics, marketing considerations (including distribution needs and consumer needs), environmental and waste management issues, and cost. Not only is balancing so many factors difficult, but also it requires a different analysis for each product, considering factors such as the properties of the packaging material, the type of food to be packaged, possible food/package interactions, the intended market for the product, desired product shelf-life, environmental conditions during storage and distribution, product end use, eventual package disposal, and costs related to the package throughout the production and distribution process. Some of these factors are interrelated: for example, the type of food and the properties of the packaging material determine the nature of food–package interactions during storage. Other times, the factors are at odds with each other: for example, single-serving packaging meets consumer needs, but bulk packaging is better for environmental reasons(24).

Safety of Novel Food packaging Material

Food packaging based on polymer nanomaterials

Polymer nanotechnology is actually developed mainly to improve barrier performance pertaining to gases such as oxygen and carbon dioxide. It is proved also to enhance the barrier performance to ultraviolet rays, as well as to add strength, stiffness, dimensional stability, and heat resistance. Once perfected, sure from a safety point of view and produced at a competitive ratio cost/performances, the new PNFP will be very attractive for extensive applications. The use of polymer nanotechnology can in fact extend and implement all the principal functions of the package (containment, protection and preservation, marketing and communication) [**21**]. This is the reason why many of the world's largest food packaging companies are actively exploring the potential of polymer nanotechnology in order to obtain new food packaging materials with improved mechanical, barrier and antimicrobial properties and also able to trace and monitor the condition of food during transport and storage. In particular the following main applications for polymer nanomaterials for food packaging will be discussed:

1. Improved" PNFP – the presence of nanoparticles in the polymer matrix materials improves the packaging properties of the polymer-flexibility, gas barrier properties, temperature/moisture stability;
2. Active" PNFP – the presence of nanoparticles allows packages to interact with food and the environment and play a dynamic role in food preservation;
3. Intelligent" PNFP – the presence of nanodevices in the polymer matrix can monitor the condition of packaged food or the environment surrounding the food and can also act as a guard against fraudulent imitation.

Concerns on environment and health safety

The foreseeable extensive use of nanotechnologies by food packaging industry, as well as by any other secsector using nanotechnology is stirring up environment and health safety concerns. Although these cases seem to give some reassurance about safety, the number of tests on migration is too limited and further investigation need to be performed before using these materials. The presence of nanoparticles embedded in packaging film can have also positive influence on the migration from food packaging into food of chemicals that may produce potential adverse health effects. de Abreu (10) addressed the migration of caprolactam, 5-chloro-2-(2,4-dichlorophenoxy) phenol (triclosan) and trans,trans-1,4-diphenyl-1,3-butadiene (DPBD) from polyamide and polyamide-nanoclays to different types of food simulants. The presence of polymer nanoparticles was found to slow down the rate of migration of those substances from the matrix polymer into the food up to six times. Little is known about what happens if these nanomaterials get into the body. The risk assessment of nanomaterials after ingestion has been studied only for few of the nanoparticles used in food packaging. Some results on TiO2 (45), Ag nanoparticles (20) and carbon [39] nanoparticles/nanotubes show that nanoparticles can enter circulation from the gastro-intestinal tract. These processes are likely to depend on the physical–chemical properties of the nanoparticles, such as size, and on the physiological state of the organs of entry. The translocation fractions seem to be rather low; however, this is subject of current intense research. After the nanoparticles have reached the blood circulation, the liver and the spleen are the two major organs for distribution. Circulation time increases drastically when the nanoparticles are hydrophilic and their surface is positively charged.

For certain nanoparticles all organs may be at risk as, for all organs investigated so far, either the chemical component of the nanoparticles or the nanoparticles themselves could be detected, indicating nanoparticle distribution to these organs. These organs include the brain and testis/the reproductive system. Distribution to the foetus in utero has also been observed. As the knowledge of the long-term behaviour of nanoparticles is very limited, a conservative estimate must assume that insoluble nanoparticles may accumulate in secondary target organs during chronic exposure with consequences not yet studied. There is a specific concern considering the possible migration of nanoparticles into the brain and unborn foetus. Research in both of these areas has to be conducted in order to either confirm or reject the hypothesis of nanoparticlesassociation with various brain diseases. The effect of other particles used in food packaging on the health is under investigation, like ZnO nanoparticles [23] and fullerenes[46].

antimicrobial biodegradable packaging

Antimicrobial packaging can extend the shelf life and safety of foods by preventing the growth of both pathogenic and spoilage microorganisms as a result of the extension of their lag phase and/or by the reduction of their growth rate (15, 29). Antimicrobial films have been developed for the delivery of lantibiotic bacteriocins like nisin and lacticin 3147 (8,36), uncharacterized bacteriocins and class IIa bacteriocins such as pediocin (26,27). However, other known class IIa bacteriocins have not yet been used in this manner (11). Antimicrobials can be added to food formulations directly or by slow release from packaging materials. Direct addition of antimicrobials to foods results in an immediate reduction of bacterial populations but may not prevent the recovery of injured cells or the growth of cells that were not destroyed by direct addition if residues of the antimicrobial are rapidly depleted (47). Antimicrobial packaging is a technology that inhibits or retards the proliferation of microorganisms in foods, thus extending the shelf life of the product (1). The application of antimicrobial films allows formigration of the antimicrobial to the coating surface and provides a continuous antimicrobial effect on the food during extended exposure. Use of polymers as carriers of antimicrobials not only permits controlled release of these antimicrobials but also prevents dramatic reductions in their antimicrobial activities due to their affinity for food particles and inactivation by components in foods. It also reduces the amount of active agent required, satisfying consumer demand for fewer additives. Several compounds have been proposed for antimicrobial activity in food packaging, including essential oils, enzymes, and organic acids such as lauric arginate (LAE, (95% of ethyl-N-dodecanoyl-L-arginate hydrochloride)). LAE is a cationic surfactant, a derivative of lauric acid, L-arginine, and ethanol. The preparation and application of this product is described in several patent applications (32)

LAE is one of the most potent food antimicrobial agents, with a broad spectrum of antimicrobial activity, and it has been classified as GRAS (Generally Recognized as Safe) and food preservative at concentration up to 200 ppm by the Food and Drug Administration (FDA) LAE is hydrolyzed in the human body and quickly broken into natural components. Several toxicological studies were carried out with animals and human by the Huntingdon Life Science although these studies did not involved YOPIs (young, old, pregnant and immune-compromised) (33). The high antimicrobial activity of LAE has been attributed to its action on the cytoplasmic membranes of microorganisms, where it alters their metabolic processes without causing cellular lysis (32). Furthermore, LAE tends to concentrate in the aqueous phase of products, where most bacterial action occurs, because of its low oil–water equilibrium partition coefficient. LAE has been verified to be nontoxic and is metabolized rapidly to naturally occurring amino acids,mainly arginine and ornithine, after consumption. To date, the use of LAE as an antimicrobial agent in food products has been well reported in various studies (25,38,40). However, limited information is available concerning antimicrobial activity when LAE is applied via a packaging system.

Antimicrobial solution in paper packaging

The most widely used materials in food and drink packaging are various kinds of papers and boards which are usually wax-coated to improve their water-resistance and increase the shelf-life of the packaged products(**37,42**). Constituents of these packaging materials can diffuse into food products and significant concentrations of packaging constituents of potential health concern have been identified in foods (**2,44**). The possibility explored in the study presented here is to use these migration processes to improve the storage characteristics and shelf-life of

the packaged foods, by adding an active compound to the wax formulation before coating, thus creating an active packaging material. Such material is here defined as a type of packaging material that extends the shelf-life or improves the safety or sensory properties of food while maintaining its quality **(29)** The challenges faced by the food industry associated with preserving foodstuffs have become increasingly complex since customers and retailers are demanding not only increasingly long shelf-lives and greater protection from various risks (notably microbial spoilage), but also minimal processing of food that changes its organoleptic qualities. Many approaches have been proposed for controlling microbial growth in foods, including modified atmosphere packaging (MAP), and use of chemical preservatives, high pressure, electric or magnetic fields, or irradiation (**17**), but one of the most novel and promising approaches is to use an active, antimicrobial packaging material. This is an important new approach that could solve many problems associated with food distribution and safety. Episodes of infection, such as those that recently appeared in the USA due to the contamination of bagged spinach by Escherichia coli could be avoided simply by using an active packaging material.

Antimicrobial food packaging in meat industry

Antimicrobial packaging is a promising form of active food packaging, in particular for meat products. Since microbial contamination of these foods occurs primarily at the surface, due to post-processing handling, attempts have been made to improve safety and to delay spoilage by use of antibacterial sprays or dips. However, direct surface application of antibacterial substances onto foods have limited benefits because the active substances are neutralized on contact or diffuse rapidly from the surface into the food mass. On the other hand, incorporation of bactericidal or bacteriostatic agents into meat formulations may result in partial inactivation of the active substances by product constituents and is therefore expected to have only limited effect on the surface microflora. Therefore, the use of packaging films containing antimicrobial agents could be more efficient, by slow migration of the agents from the packaging material to the surface of the product, thus helping maintain high concentrations where they are needed. If an antimicrobial can be released from the package during an extended period, the activity can also be extended into the transport and storage phase of food distribution. Antimicrobial substances incorporated into packaging materials can control microbial contamination by reducing the growth rate and maximum growth population and/or extending the lag-phase of the target microorganism, or by inactivating microorganisms by contact. Some advantages of using edible coatings and films on meat and meat products have been discussed recently by Edible coatings could:

- help alleviate the problem of moisture loss during storage of freshor frozen meats
- hold juices of fresh meat and poultry cuts when packed in retail plastic trays;
- reduce the rate of rancidity-causing lipid oxidation and brown coloration-causing myoglobin oxidation;
- reduce the load of spoilage and pathogen microorganisms on the surface of coated meats; and
- restrict volatile flavour loss and foreign odour pick-up(**12**).

As an application of active packaging, edible coatings carrying antioxidants or antimicrobials can be used for direct treatment of meat surfaces. In the case of edible films and coatings, selection of the incorporated active agents is limited to edible compounds. Because they have to be consumed with edible film/coating layers and foods together, their edibility and safety are essential. In Fig.4 Effect of antimicrobial plastic film on Aspergillus niger is shown.

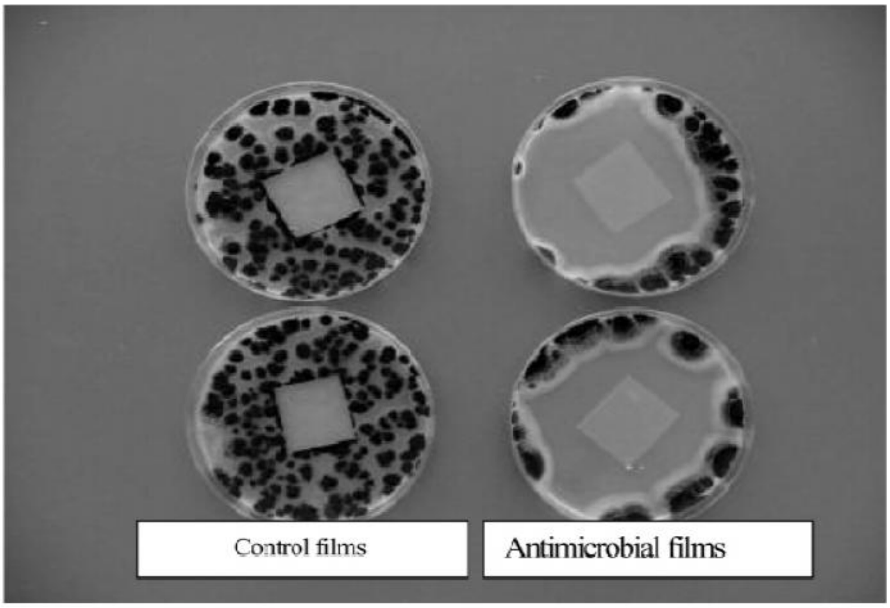

Fig. 4. Effect of antimicrobial plastic film on Aspergillus niger. Agar diffusion method(1).

Conclusion

The purpose of packaging is to preserve the quality and safety of the product it contains from the time of manufacture to the time it is used by the consumer. An equally important function of packaging is to protect the product from physical, chemical, or biological damage. When packaging fails to perform its protective function, the result may be an unsafe product, especially when there is a loss of integrity resulting in contamination by undesirable organisms. In recent years, the number and type of packaging properties and materials have been expanded to accommodate environmental disposability as well as package performance beyond the inherent characteristics of the packaging material. These characteristics may include enhanced shelf-life or the ability to detect other changes in the product or packaging material, as has been demonstrated with active packaging. As with all packaging developments to this point, the safety and regulatory implications must be considered if these types of technologies are to be implemented and successful. Migration of volatiles, additives, monomers and oligomers from packaging materials into food or adsorption of volatile compounds from the food by the polymer are important considerations from safety, hygienic and economic points of view. The constant introduction of novel packaging materials has increased the number of specific hazards to which humans are exposed via the migration from packaging into food. Finally, The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact.

REFERENCE

1. Appendini, P., Hotchkiss, J.H., 2002. Review of antimicrobial food packaging. Innovative Food Science and Emerging Technologies 3, 113–126.
2. Arvanitoyannis, I.S., Bosnea, L. (2004). Migration of substances from food packaging materials to foods, Crit. Rev. Food Sci. Nutr. 44 63–76.
3. Bang, D.Y., Kyung, M., Kim, M.J., et al. (2012). Human Risk Assessment of Endocrine-Disrupting Chemicals Derived from Plastic Food Containers. Comprehensive Reviews in Food Science and Food Safety. Vol:11.
4. Begley, T.M. (1997). Methods and approaches used by FDA to evaluate the safety of food packaging materials, Food Additives and Contaminants, 14:6-7, 545-553.
5. Brody A.L.(2003). Nano and food technology converge. Food Technol.60:92–4.
6. Chaudhry, Q., Scotter, M., Blackburn, J., Ross B., Boxall, A., Castle, L., Aitken, R., Watkins, R. (2008).Applications and implications of nanotechnologies for the food sector. Food Addit Contam;25:241–58.
7. Coles, R. (2003). Food packaging technology. London, U.K.: Blackwell Publishing, CRC Press. p 1-31.
8. Coma, V., Sebti, I., Pardon, P., Deschamps, A., Pichavant, F.H.. (2001). Antimicrobial edible packaging based on cellulosic ethers, fatty acids, and nisin incorporation to inhibit Listeria innocua and Staphylococcus aureus. Journal of Food Protection 94, 470–475.
9. Cooksey, K. (2007). Interaction of food and packaging contents. InC. L. Wilson (Ed.), Intelligent and active packaging for fruits and vegetables (pp. 201e237). CRC Press.
10. De, Abreu., Cruz, J.M., Angulo, I. Losada, P.P. (2010). Mass transport studies of different additives in polyamide and exfoliated nanocomposite polyamide films for food industry. Packag Technol Sci 23:59–68.
11. Drider, D., Fimland, G., Héchard, Y., McMullen, L.M., Prévost, H., 2006. The continuing story of class IIa bacteriocins. Microbiology and Molecular Biology Reviews 72, 564–582.
12. Gennadios, A., Hanna, M. A., & Kurth, L. B. (1997). Application of edible coatings on meat, poultry and seafoods: a review. Lebensmittel- Wissenschaft & Technologie, 30, 337–350.
13. Giacin, J. R. (1995). Factors affecting permeation, sorption and migration processes in package-product system. In P. Ackermann, M. Ja¨gerstad, & T. Ohlsson (Eds.), Foods and packaging materials Chemical interactions (pp. 12e22). Cambridge: The Royal Society of Chemistry.
14. Grob, K. (2002). Comprehensive analysis of migrates from food-packaging materials: a challenge. Food Additives and Contaminants, 19:S1, 185-19.
15. Han, J.H., (2000). Antimicrobial food packaging. Food Technology 54, 56–65.
16. Havelaar, A.H., Stanely B., De jong, A., De jonge, R., Zwietering ,M.H., Kuile, B.H.T. (2010). Fture challenges to microbial food safety. Internation journal of food microbiology. 139: S79-S94.
17. Holley, R.A., Patel., D. (2005) . Improvement in shelf-life and safety of perishable foods by plant essential oils and smoke antimicrobials, Food Microbiol. 22: 273–292.
18. Hotckiss, J. H. (1995). Overview on chemical interactions between food and packaging materials. In P. Ackermann, M. Jagerstad, & Ohlsson (Eds.), Foods and packaging materials Chemical interactions (pp. 3e11). Cambridge: The Royal Society of Chemistry.and safety. Food Additi_es and Contaminants, 14Ž6_7., 601_607.
19. Kester, J. J., & Fennema, O. R. (1986). Edible films and coatings: a review. Food Technology, 48(12), 47e59.

20. Kim, Y.S., Kim, J.S., Cho, H.S., Rha, D.S., Kim, J.M., Park, J.D., Choi, B.S., Lim, R., Chang, H.K., Chung, Y.H., Kwon, I.H., Jeong, J., Han, B.S., Yu, I.J. (2008). Twentyeight day oral toxicity, genotoxicity, and gender-related tissue distribution of silver nanoparticles in Sprague–Dawley rats. Inhal Toxicol.20:575–83.
21. Lagaron, J.M, Gimenez, E, Sánchez-García, M.D, Ocio, M.J, Fendler, A. (2007). Novel nanocomposites to enhance quality and safety of packaged foods. In: Food contact polymers. Shawbury, UK: Rapra Technologies,. Paper 19:1-5.
22. Lee, D. S., Yam, K. L., & Piergiovanni, L. (2008). Food packaging science and technology. CRC Press.
23. Lin, D., Xing, B.(2008). Root uptake and phytotoxicity of ZnO nanoparticles. Environ Sci Technol;42:5580–5.
24. Marsh. K., Bugusu, B. (2007). Food Packaging—Roles, Materials, and Environmental Issues. Journal of food science. Vol.72: Nr3.
25. Martin, E.M., Griffis, C.L., Vaughn, K.L.S., O'Bryan, C.A., Friedly, E.C., Marcy, J.A., Ricke, S.C., Crandall, P.G., Lary Jr., R.Y., (2009). Control of Listeria monocytogenes by lauric arginate on frankfurters formulated with or without lactate/diacetate. Journal of Food Science 74, M237–M241.
26. Mauriello, G., Ercolini, D., La Storia, A., Casaburi, A., Villani, F., (2004). Development of polythene films for food packaging activated with an antilisterial bacteriocin from Lactobacillus curvatus 32Y. Journal of Applied Microbiology 97, 314–322.
27. Ming, X., Weber, G.H., Ayres, J.W., Sandine, W.E., (1997). Bacteriocins applied to food packaging materials to inhibit Listeria monocytogenes on meats. Journal of Food Science 62, 413–415.
28. Munro, I.C., Hlywka, J.J., Kennepohl, E.M. (2002). Risk assessment of packaging materials. Food Additives and Contaminants, 19:S1, 3-12.
29. Quintavalla, S., Vicini, L. (2002). Antimicrobial food packaging in meat industry, Meat Sci. 62 373–380.
30. Risch, S, J.(2009). Food Packaging History and Innovations. J. Agric. Food Chem. 57, 8089–8092.
31. Robertson, G.L. (2006). Food Packaging Principles and Practice, 2nd edn. Boca Raton, Florida: CRC Press.
32. Rodriguez, E. (2004). Cellular effects of monohydrochloride of L-arginine, N-alphalauroyl ethylester (LAE) exposure on Salmonella typhimurium and Staphylococcus aureus. Journal of Applied Microbiology 96, 903–912.
33. Ruckman, S.A., Rocabayera, X., Borzelleca, J.F., Sandusky, C.B. (2004). Toxicological and metabolic investigations of the safety of N-alpha-lauroyl-L-arginine ethyl ester monohydrochloride (LAE). Food and Chemical Toxicology 42, 245–259.
34. Sajilata, M. G., Savitha, K., Singhal, R. S., & Kanetkar, V. R. (2007). Scalping of flavors in packaged foods. Comprehensive Reviews in Food Science and Food Safety, 6, 17e35.
35. Shapiro, A., Mercier, C. (1994). Safe food manufacturing. the Science of the Total Environment journal. 143: 75-92.
36. Siragusa, G.R., Cutter, C.N., Willett, J.L. (1999). Incorporation of bacteriocin in plastic retains activity and surface growth of bacteria in meat. Food Microbiology 16, 229–235.
37. Song,Y.S., Park,H.J., Komolprasert, V.(2000). Analytical procedure for quantifying five compounds suspected as possible contaminants in recycled paper/paperboard for food packaging, J. Agric. Food Chem. 48 5856–5859.
38. Soni, K.A., Nannapaneni, R., Schilling, M.W., Jackson, V. (2010). Bactericidal activity of lauric arginate in milk and Queso Fresco cheese against Listeria monocytogenes cold growth. Journal of Dairy Science 93, 4518–4525.

39. Takagi, A., Hirose A., Nishimura, T., Fukumori, N., Ogata, A., Ohashi, N., Kitajima, S., Kanno, J. (2008). Induction of mesothelioma in p53+/−mouse by intraperitoneal application of multi-wall carbon nanotube. J Toxicol Sci;33:105–16.
40. Taormina, P.J., Dorsa, W.J. (2009). Inactivation of Listeria monocytogenes on hams shortly after vacuum packaging by spray application of lauric arginate. Journal of Food Protection 72, 2517–2523.
41. Tehrany, E.A., Desobry, S. (2004). Partition coefficients in food/packaging systems: a review, Food Additives and Contaminants, 21:12, 1186-1202.
42. Triantafyllou, V.I., Akrida-Demertzi, K., Demertzis, P.G. (2007). A study on the migration of organic pollutants from recycled paperboard materials to solid food matrices, Food Chem. 101 1759–1768.
43. Vermeiren, L., Devlieghere, F., Van Beest, M., De Kruijf, N., Debevere. J.(1999). Developments in the active packaging of foods, Trends Food Sci. Technol. 55 841–846.
44. Vitrac, O., Mougharbel, A., Feigenbaum, A. (2007). Interfacial mass transport properties which control the migration of packaging constituents into foodstuffs, J. Food Eng. 79:1048–1064.
45. Wang, J., Zhou, G., Chen, C., Yu, H., Wang, T., Ma, Y., Jia, G., Gao,. Y, Li, B., Sun, J., Li Y, Jiao, F., Zhao, Y., Chai, Z.(2007). Acute toxicity and biodistribution of different sized titanium dioxide particles in mice after oral administration.Toxicol Lett;168:176–85.
46. Xia X.R, Monteiro-Riviere N.A, Riviere J.E. (2010). Skin penetration and kinetics of pristine fullerenes (C60) topically exposed in industrial organic solvents. Toxicol Appl Pharmacol. 242:29–37.
47. Zhang, Y., Yam, K., Chikindas, M. (2004). Effective control of Listeria monocytogenes by combination of nisin formulated and slowly released into a broth system. International Journal of Food Microbiology.15–22.