IJFANS
International Journal of Food And Nutritional Sciences

Volume 4, Issue 1, Jan-Mar 2015, www.ijfans.com e-ISSN: 2320-7876

INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

IMPACT FACTOR ~ 1.021

Official Journal of IIFANS

e-ISSN 2320 –7876 *www.ijfans.com*
Vol.4, Iss.1, Jan-Mar 2015

Review Paper ***Open Access***

ACTIVE PACKAGING: CONCEPTS AND APPLICATIONS

Shivalkar Yadav. K[1*] and Prabha. R[2] and K. Renuka[2]
[1*]Assistant Quality Control Officer, APDDCF, Hyderabad, [2]Department of Dairy Microbiology, Dairy Science College, KVAFSU, Hebbal, Bengaluru, India

[*]Corresponding Author: shivalkaryadav@gmail.com

Received on: 20th January, 2015 **Accepted on: 7th March, 2015**

ABSTRACT

The purpose of food packaging is to preserve the quality and safety of the food it contains from the time of manufacture to the time it is used by the consumer. Recently, 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. One such development is the active food packaging technology. Active packaging refers to the incorporation of certain additives into packaging film or within packaging containers with the aim of maintaining and extending product shelf life. It includes additives or freshness enhancers that are capable of scavenging oxygen; adsorbing carbon dioxide, moisture, ethylene and/or flavour/odour taints; releasing ethanol, sorbates, antioxidants and/or other preservatives; and/or maintaining temperature control.“Active packaging technologies involve interactions between the food, the packaging materials and the internal gaseous atmosphere and main objectives are: shelf life extension, easier handling and preserve quality.

Key words: Active Packaging, Oxygen Scavengers, Carbon dioxide Scavengers, Emitters, Absorbers, Food Safety.

INTRODUCTION

New food packaging technologies are developing as a response to consumer demands or industrial production trends towards mildly preserved, fresh, tasty and convenient food products with prolonged shelf-life and controlled quality. In addition, changes in retailing practices (such as market globalization resulting in longer distribution of food), or consumers way of life (resulting in less time spent shopping fresh food at the market and cooking), present major challenges to the food packaging industry and act as driving forces for the development of new and improved packaging concepts that extend shelf-life while maintaining and monitoring food safety and quality. Traditional food packaging is meant for mechanical supporting of otherwise non-solid food, and protecting food from external influences, like microorganisms, oxygen, off-odours, light etc. and, by doing so, guaranteeing convenience in food handling and preserving the food quality for an extended time period. The key safety objective for these traditional materials in contact with foods is to be as inert as possible, i.e., there should be a minimum of interaction between food and packaging. In the last decades, however, one of the most innovative developments in the area of food packaging is the ‘active and intelligent’ (A&I) packaging, based on deliberate interactions with the food or the food environment. The purpose of the ‘active packaging’ is the extension of the shelf-life of the food and the maintenance or even improvement of its quality (Dario Dainelli et al., 2008).

Active packaging as originally described by Labuza and Breene (1989) is used successfully to increase the shelf life of processed foods and meet consumer demands in terms of providing high-quality products that are also fresh and safe. Active packaging has been used with many food products and is being tested with numerous others food applications that have benefited from active packaging technology. It should be noted that all food products have a unique deterioration mechanism that must be understood before applying this technology.

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). The intrinsic properties of the polymer can give rise to the active function next to, e.g., the intentional grafting of an active group or through the introduction of an active monomer inside the polymer chain. An active agent can be incorporated inside the packaging material or onto its surface, in multilayer structures or in particular elements associated with the packaging such as sachets, labels or bottle caps. The nature of the active agents that can be added is very diverse (organic acids, enzymes, bacteriocins, fungicides, natural extracts, ions, ethanol etc.) as well as the nature of the materials into which they are included such as papers, plastics, metals or combinations of these materials. The active systems can be placed outside the primary packaging, in between different parts of the primary packaging or inside the primary packaging. In this last case, the systems can be in contact only with the atmosphere surrounding the food, in contact with the food surface or placed inside the food itself (for liquid foods). This diversity accounts for the innovation potential in this field but it also represents a real challenge for the safety assessment

Table I: Examples of active packaging applications for use within the food industry

Absorbing/scavenging properties	Oxygen, carbon dioxide, moisture, ethylene, flavours, taints, UV light
Releasing/emitting properties	Ethanol, carbon dioxide, antioxidants, preservatives, sulphur dioxide, flavours
Removing properties	Catalyzing food component removal: lactose, cholesterol
Temperature control	Insulating materials, self-heating and self-cooling packaging, temperature-sensitive packaging
Microbial and quality control	UV and surface-treated packaging materials

It performs some desired functions other than merely providing a barrier to the external environment. At the present time, active and intelligent packaging systems are mainly used in Asia or the United States, whereas in Europe its use is not widespread. The active or intelligent packaging should fulfill following conditions:

a. The materials must be appropriate and effective for their intended use.

b. Materials and articles, including active and intelligent materials and articles, shall be manufactured in compliance with good manufacturing practice

c. The materials must display information about the use or the permitted uses and other relevant information, such as name and quantity of substances released by the active component

d. Mandatory labeling with the words “DO NOT EAT” must be provided to enable consumers to distinguish nonedible parts, when these may be perceived as edible. This information must be visible, legible and indelible.

Table. II Active packaging and its effect on some foods

Author	Types of Food Package	Results
Gomes et al. 2009	Oxygen Scavenger	Increases shelf life of Cheese Spread
Gomez-Estaca et al. 2009	Antimicrobial	Antimicrobial activity against *Lactobacillus acidophilus*,*Pseudomonas fluorescens*, *Listeria innocua*, and *Escherichia coli* in Raw fish products and salmon
Granda-Restrepo et al.2009	Antioxidant	Quality improvement in milk powder
Gutierrez et al. 2009	Odour releaser and antimicrobial	Quality improvement and antimicrobial activity in roast beef
Guynot et al. 2003	Oxygen Scavenger	Increase the shelf life in cakes
Mexis et al. 2010	Oxygen Scavenger	Quality improvement and increase the shelf life in darkchocolates
Moraes et al. 2007	Antimicrobial	Antimicrobial activity against filamentous fungi and yeast inbutter
Baiano et al 2004	Oxygen scavenger	Inhibition of ascorbic acid degradation in beverages
Bailen et al. 2006	Ethylene scavenger	Reducing the rate of softening in tomatoes
de Oliveira et al. 2008	Antimicrobial	Quality improvement of apple slices
Zinoviadou et al. 2010	Antimicrobial	Increase the shelf life in fresh beef
Yingyuad et al. 2006	Antimicrobial	Increase the shelf life in grilled pork
Rodríguez et al. 2008	Antimicrobial	Antimicrobial activity against *Rhizopusstolonifer* in Sliced bread

This review is regarding active-packaging technologies; different types of devices; the scientific principles behind them; the principal food applications; the food safety and regulatory issues that needs to be considered by potential users.

OXYGEN SCAVENGERS

Oxygen scavengers were first marketed in Japan in 1976 by the Mitsubishi Gas Chemical Co. Ltd under the trade name Ageless^{TM}. Oxygen scavengers are the most commercially important among active packaging. The common most well known oxygen scavengers are applied in the form of small sachet containing various iron based powders combined with a suitable catalyst which have capability of reducing oxygen levels to less than 0.01% is the pack. Non-metallic scavengers use organic reducing agents such as ascorbic acid, ascorbate salts or catechol. Enzymic oxygen scavenging systems are also used with either glucose oxidase or ethanol oxidase which could be incorporated into sachets, adhesive labels or immobilised onto packaging film surfaces (Rooney, 1995).

Some examples of oxygen scavengers used in food industry (Rooney, 1995, 1998, 2000; Castle, 1996) are:

- Laminate containing a ferrous oxygen scavenger which can be thermoformed into a tray which has been used commercially for cooked rice
- Oxygen scavenging plastic (PET) beer bottles
- Light activated oxygen scavenger plastic packaging materials for Beverage industry

Oxygen can trigger or accelerate oxidation and also facilitate the growth of aerobic microorganisms, lowering food quality, and shortening the shelf-life. Strategies leading to increasing the gas barrier properties include the use of active oxygen scavengers in the packaging in sachets, labels, or included in the polymer layers, or as passive nano composites offering a delay in the oxygen transport due to an increased tortuosity in the oxygen pathway (Brody et al., 2008; Llorens et al., 2011). Oxygen absorbers are the most widely used active packaging concepts commercialized for the first time in 1970 by Mitsubishi Gas Chemical Company (Mexis and Kontominas, 2010). Oxygen scavengers can remove oxygen that permeates through the packaging material into the package during storage and reduce residual oxygen that may have been trapped inside the package prior to sealing. Currently, one of the most effective and commonly used oxygen scavengers are oxygen scavenging sachets containing iron powder (Vermeiren et al., 2003; Byun et al., 2011; Byun et al., 2012). O_2 scavenging capacity depends on the product. Commercial O_2 scavengers containing active iron oxide can reduce the internal O_2 content to less than 0.05% within 9 h (Ooraikul, 1991; Lee, 2010). Mexis et al. (2010) studied the effect of polyethylene terephthalate/low density polyethylene (PET/LDPE), and polyethylene terephthalate coated with SiOx/low density polyethylene (PET -SiOx/LDPE) on quality retention of dark chocolate with hazelnuts under vacuum, N_2 and an oxygen absorber in the dark at 20 °C for a period of 12 months. Samples packaged in PET - SiOx/LDPE under N_2 or vacuum showed a small increase in PV value (from 0.80 to 2.19 and 2.37 meq O_2/kg chocolate fat, respectively) while for samples packaged in PET//LDPE under N_2 or vacuum packaged a fivefold increase was recorded.

CARBON DIOXIDE SCAVENGERS/EMITTERS

There are many commercial sachet and label devices which can be used to scavenge or to emit carbon dioxide. The use of carbon dioxide scavengers is particularly used in packing fresh roasted or ground coffees that produce significant volumes of carbon dioxide. A mixture of calcium oxide and activated charcoal has been used in polyethylene coffee pouches to scavenge carbon dioxide. 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).

The main food applications for these dual-action oxygen scavenger/carbon dioxide emitter sachets and labels have been with snack food products, e.g. nuts and sponge cakes (Rooney, 1995). High carbon dioxide levels (10 -80%) are desirable for foods such as meat and poultry in order to inhibit surface microbial growth and extend shelf life. Removal of oxygen from the package creates a partial vacuum, which may result in the collapse of flexible packaging. Also, when a package is flushed with a mixture of gases including carbon dioxide, the carbon dioxide dissolves in the product creating a partial vacuum. In such cases, the simultaneous release of carbon dioxide from inserted sachets, which consume oxygen, is desirable. Such systems are based on either ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate (Rooney, 1995; Kerry et al., 2006). Carbon dioxide absorbers (sachets), consisting of either calcium hydroxide and sodium hydroxide, or potassium hydroxide, calcium oxide and silica gel, may be used to remove carbon dioxide during storage in order to prevent bursting of the package (Ahvenainen, 2003; Kerry et al., 2006). The reactant commonly used to scavenge CO_2 is calcium hydroxide, which, at a high enough water activity, reacts with CO_2 to form calcium carbonate: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$ A disadvantage of this CO_2 scavenging substance is that it scavenges carbon dioxide from the package headspace irreversibly and results in depletion of CO_2, which is not always desired (Ahvenainen, 2003).

ETHYLENE SCAVENGERS

The control of ethylene in stored conditions plays a key role in prolonging the post harvest life of many types of fresh produce (Terry et al 2007). Most fruits and vegetables release ethylene after they are harvested. Ethylene is a phytohormone that initiates and accelerates ripening, produces softening and degradation of chlorophylls, and inevitably leads to deterioration of fresh or minimally processed fruits and vegetables. Ethylene scavengers are useful for preserving ethylene-sensitive fruits and vegetables such as apples, bananas, mangos, tomatoes, onions, carrots.

MECHANISM OF ACTION

a.) One of the main mechanisms of action of ethylene scavengers is based on the use of potassium permanganate, which oxidizes ethylene to carbon dioxide and water. The typical permanganate content is between 4%and 6% (Abe and Watada 1991). Potassium permanganate oxidizes ethylene and changes color from purple to brown, and thus, a color change indicates its residual ethylene absorbing capacity, but because of its toxicity potassium permanganate cannot be used in direct contact with food.

b.) Other systems are based on the ability of certain materials to absorb ethylene, alone or with any oxidizing agent. For example, palladium has been shown to have a higher ethylene adsorption capacity than permanganate-based scavengers in situations of high relative humidity (Smith et al 2009). LDPE and HDPE polyethylene films as packaging material are able to absorb ethylene; ethanol, ethyl acetate, ammonia, and hydrogen sulfide are used in food industry. These films keep food fresh for longer and eliminate odours.

ETHANOL EMITTERS

Ethanol is an antimicrobial agent particularly effective against mold but can also inhibit the growth of yeasts and bacteria. Ethanol can be sprayed directly onto food products just prior to packaging. A practical and safer method of generating ethanol is through the use of ethanol-emitting films and sachets. All of these films and sachets contain absorbed or encapsulated ethanol in a carrier material which allows the controlled release of ethanol vapour (Rooney, 1995).

PRESERVATIVE RELEASERS

There is a potential use for antimicrobial and antioxidant packaging films which have preservative properties for extending the shelf life of a wide range of food products. Some commercial antimicrobial films and materials have been introduced, primarily in Japan. One widely reported product is a synthetic silver zeolite which is in contact with packaging film that release slowly antimicrobial silver ions into the surface of food products (Rooney, 1995).

The antimicrobial agents generally used on packaging materials include organic acids, e.g. propionate, benzoate and sorbate, bacteriocins, e.g. nisin, spice and herb extracts, e.g. from rosemary, cloves, horse radish, mustard, cinnamon and thyme, enzymes, e.g. peroxidase, lysozyme and glucose oxidase, chelating agents, e.g. EDTA, inorganic acids, e.g. sulphur dioxide and chlorine dioxide and antifungal agents, e.g. imazalil and benomyl. The major potential food applications for antimicrobial films include bread, cheese, fruit and vegetables (Gray, 2000).

MOISTURE ABSORBERS

A major cause of food spoilage is excess moisture. Soaking up moisture by using various absorbers or desiccants is very effective at maintaining food quality and extending shelflife by inhibiting microbial growth and moisture related degradation of texture and flavour.Excess moisture cause food spoilage which can be reduced by using various absorbers or desiccants which in turn helps in maintaining food quality and extending shelf life by inhibiting microbial growth and moisture related degradation of texture and flavour (Rice,1994; Rooney, 1995).

Several companies manufacture moisture-drip absorbent pads, sheets and blankets which consist of two layers of a micro porous non-woven plastic film, such as polyethylene or polypropylene, between which is placed a superabsorbent polymer capable of absorbing up to 500 times its own weight with water which is used for foods such as meats, fish, poultry, fruit and vegetables. Typical superabsorbent polymers include polyacrylate salts, carboxymethyl cellulose (CMC) and starch copolymers which have a very strong affinity for water. Moisture drip absorber pads are commonly placed under packaged fresh meats, fish and poultry to absorb unsightly tissue drip exudate. Larger sheets and blankets are used for absorption of melted ice from chilled seafood during air freight transportation, or for controlling transpiration of horticultural produce Micro porous sachets of desiccant inorganic salts such as sodium chloride have been used for the distribution of tomatoes in USA. Another example is an innovative fibreboard box which functions as a humidity buffer on its own without relying on a desiccant insert which is used for fruit or vegetables (Rooney, 1995).

FLAVOUR/ODOUR ADSORBERS

Addition of essences and odours can increase the desirability of the food to the consumer, to improve the aroma of fresh product itself, or to enhance the flavor of food when the package is opened. These flavors and aromas are released slowly and evenly in the packaged product during its shelf life or release can be controlled to occur during opening the package or food preparation. Gradual release of odours can offset the natural loss of taste or smell of products with long shelf lives (Almenar et al 2009).

TEMPERATURE CONTROLLED PACKAGING:

Temperature control active packaging includes the use of innovative insulating materials, self-heating and self-cooling cans. For example, to guard against undue temperature abuse during storage and distribution of chilled foods, special insulating materials have been developed. One such material is Thinsulate™ (3M Company, USA) which is a special non-woven plastic with many air pore spaces. Another approach for maintaining chilled temperatures is to increase the thermal mass of the food package so that it is capable of withstanding temperature rises. The Adenko Company of Japan has developed and marketed a Cool Bowl™ which consists of a double walled PET container in which an insulating gel is deposited in between the walls (Labuza and Breene, 1989). Self-heating cans and containers have been commercially available for decades and are particularly popular in Japan (Day, 2003). Self-heating aluminium and steel cans and containers for sake, coffee, tea and ready meals are heated by an exothermic reaction when quicklime and water positioned in the base are mixed. During 2001 in the UK, Nestl´e introduced a range of Nescaf´e coffees in self-heating insulated cans that used the quicklime and water exothermic reaction.

FOOD SAFETY, CONSUMER ACCEPTABILITY AND REGULATORY ISSUES:

At least four types of food safety and regulatory issues related to active packaging of foods need to be addressed. First, any need for food contact approval must be established before any form of active packaging is used. Second, it is important to consider environmental regulations covering active-packaging materials. Third, there may be a need for labelling in cases where active packaging may give rise to consumer confusion. Fourth, it is pertinent to consider the effects of active packaging on the microbial ecology and safety of foods (Rooney, 1995). All of these issues are addressed in an EC funded *Actipack* project which aims to evaluate the safety, effectiveness, economic and environmental impact and consumer acceptance of active and intelligent packaging (De Kruijf, 2000).

Food contact approval will often be required because active packaging may affect foods in two ways. Active packaging substances may migrate into the food or may be removed from it. Migrants may be intended or unintended. Intended migrants include antioxidants, ethanol and antimicrobial preservatives which would require regulatory approval in terms of their identity, concentration and possible toxicology effects. Unintended migrants include various metal compounds which achieve their active purpose inside packaging materials but do not need to, or should not, enter foods. Food additive regulations require identification and quantification of any such unintended migration. Environmental regulations covering reuse, recycling, and identification to assist in recycling or the recovery of energy from active packaging materials need to be addressed on a case-by-case basis. European Union companies using active packaging as well as other packaging need to meet the requirements of the Packaging Waste Directive (1994) and consider the environmental impact of their packaging operations

Food labeling is currently required to reduce the risk of consumers ingesting the contents of oxygen scavenger sachets or other in-pack active-packaging devices. Some active packages may look different from their passive counterparts. Therefore it may be advisable to use appropriate labeling to explain this difference to the consumer even in the absence of regulations. Finally, it is very important for food manufacturers using certain type of active packaging to consider the effects this will have on the microbial ecology and safety of foods. For example, removing all the oxygen from within the packs of high *a*w chilled perishable food products may stimulate the growth of anaerobic pathogenic bacteria such as *Clostridium botulinum*. Specific guidance is available to minimize the microbial safety risks of foods packed under reduced oxygen atmospheres (Betts, 1996).

Active packaging is subjected to traditional packaging legislation, which requires that compounds are registered on positive lists and that the overall and specific migration limits are respected. This is more or less contradictory to the concept of some active packaging systems in which packaging releases substances to extend shelf life or improve quality (De Kruijf, 2000). The food industry's main concern about introducing active components to packaging seems to be that consumers may consider the components harmful and may not accept them. In Finland, a consumer survey conducted in order to determine consumer attitudes towards oxygen scavengers revealed that the new concepts would be accepted if consumers are well informed by using reliable information channels. More information is needed on the chemical, microbiological and physiological effects of various active concepts on the packaged food, i.e. in regard to its quality and safety. So far, research has mainly concentrated on the development of various methods and their testing in a model system, but not so much on functioning in food preservation with real food products. Furthermore, the benefits of active packaging need to be considered in a holistic approach to environmental impact assessment. The environmental effect of plastics-based active packaging will vary with the nature of the product/package combination, and additional additives need to be evaluated for their environmental impact (Vermeiren *et al*., 1999).

CONCLUSION

Changes in consumer preferences have led to innovations and developments in new packaging technologies. Most innovative packaging systems have the potential to increase packaging costs, and so restrict options for commercialization, especially for small and intermediate sized businesses. However, these cost increases are counterbalanced by reductions in wastage due to the enhanced quality and shelf-life of products. Therefore, a complete assessment of specific costs and benefits is the essential next step in establishing the commercial application of innovative packaging technology. Active packaging is an emerging and exciting area of food technology that can confer many preservation benefits on a wide range of food products. Active packaging is a technology developing a new trust because of recent advances in packaging, material science, biotechnology and new consumer demands. The objectives of this technology are to maintain sensory quality and extend the shelf life of foods whilst at the same time maintaining nutritional quality and ensuring microbial safety. Oxygen scavengers are by far the most commercially important subcategory of active packaging and the market has been growing steadily for the last ten years. It is predicted that the recent introduction of oxygen scavenging films and bottle caps will further help to stimulate the market in future years and the unit costs of oxygen scavenging technology will drop. Other active packaging technologies are also predicted to be used more in the future, particularly carbon dioxide scavengers and emitters, moisture absorbers and temperature control packaging. Nevertheless, the use of active packaging is becoming increasingly popular and many new opportunities in the food and non-food industries will open up for utilizing this technology in the future.

REFERENCES

- Anon. Pursuit of freshness creates packaging opportunities. Japanese Packaging News; 1995, 12, 14–15.
- Ahvenainen., R. (2003). Novel food packaging techniques. Woodhead Publishing Limited
- Abington Hall, Cambridge England.
- Ahvenainen, R. and Hurme, E. Active and smart packaging for meeting consumer demands for quality and safety. Food Additives Contaminants; 1997;14, 753–763.

- Alarcon, B. and Hotchkiss J.H. The Effect of FreshPax Oxygen-Absorbing Packets on the Shelf-Life of Foods. Technical Report, department of Food Science, Cornell University, Ithaca, NY.1993
- Ahvenainen, R., Hurme, E. and Smolander, M. Active and Smart Packaging – Novel packaging methods to assure the quality and safety of foods. SIG Pack Congress. Helsinki, 3-4 Sept. 1998. Visions. Packaging innovations today and tomorrow. SIG Pack Systems AG. Beringen. 1998, 94-115.
- Ahvenainen, R., Alakomi, H., Helander, I., Skyttä, E. and Sipiläinen- Malm, T. Hurdle Concept in Food Preservation, Technical Report, Nordic network on Minimal Processing, July 1999.
- Abe, K. and Watada, A. Ethylene absorbent to maintain quality of lightly processed fruits and vegetables. *J. Food Sci.* 1991, 56, 1589–1592.
- Almenar, E., Catala, R., Hernandez-Munoz, P. and Gavara, R. Optimization of an active package for wild strawberries based on the release of 2-nonanone. *Lwt-Food Sci. Technol*. 2009, 42, 587–593.
- Betts, G.D. (ed.) Code of Practice for the Manufacture of Vacuum and Modified Atmosphere Packaged Chilled Foods with Particular Regards to the Risks of Botulism. Guideline No. 11, Campden & Chorleywood Food Research Association, Chipping Campden, Glos., UK.1996.
- Byun, Y, Bae, H.J and Whiteside, S. (2012). Active warm-water fish gelatin film containing oxygen scavenging system. Food Hydrocolloids, 27: 250-255.
- Byun, Y., Darby, D., Cooksey, K., Dawson, P and Whiteside, S. (2011). Development of oxygen scavenging system containing a natural free radical scavenger and a transition metal. Food Chemistry, 124, 615-619.
- Baiano, A., Marchitelli, V., Tamagnone, R. and Del Nobile, M.A. Use of active packaging for increasing ascorbic acid retention in food beverages. *J. Food Sci*. 2004, 69, 502–508.
- Bailen, G., Guillen, F., Castillo, S., Serrano, M., Valero, D. and Martinez-Romero, D. Use of activated carbon inside modified atmosphere packages to maintain tomato fruit quality during cold storage. *J. Agric. Food Chem*. 2006, 54, 2229–2235.
- Brody, A. L., Bugusu, B., Han, J. H., Sand, C. K and McHugh, T. H. (2008). Innovative
- Food packaging solutions. Journal of Food Science, 73: 107-116
- Castle, D. Polymer advance doubles shelf-life. Packaging Week; 1996, 12(17), 1.
- Dainelli, D., Gontard, N., Spyropoulos, D., den Beuken, E.Z.-V and Tobback, P. (2008).
- Active and intelligent food packaging: legal aspects and safety concerns. Trends in Food Science & Technology, 19: 103-112
- Day, B.P.F. Extension of shelf-life of chilled foods. European Food and Drink Review; 1989, 4, 47–56.
- Day, B.P.F. Active packaging – a fresh approach. Brand© – The Journal of Brand Technology; 2001, 1(1), 32–41.
- De Kruijf, N. Objectives, tasks and results from the EC FAIR ‘Actipak’ research project, in Proceedings of the ‘International Conference on Active and Intelligent Packaging’, Campden & Chorleywood Food Research Association, Chipping Campden, Glos., UK; 2000,7–8 September.
- de Oliveira, T.M., Soares, N.F., de Paula, C.D. and Viana, G.A. Active packaging use to inhibit enzymatic browning of apples. *Semin. Cienc. Agrar*. 2008, 29, 117–128.
- Day B.P.F., Active packaging. 2003, *in*: Food Packaging Technologies (eds. R. Coles, D. McDowell, M. Kirwan). CRC Press, Boca Raton, FL, USA, ISBN : 9781444392180, pp. 282–302.
- Gontard, N. (2000). In: N. Gontard (Ed.), Les Emballages Actifs. Paris, France: Tech & Doc Editions, Lavoisier.
- Gray, P.N. Generation of active Microatmosphère™ environments from and in packages, in Proceedings of the ‘International Conference on Active and Intelligent Packaging’, Campden & Chorleywood Food Research Association, Chipping Campden, Glos.,UK;2000, 7–8 September.
- Gomes, C., Castell-Perez, M.E., Chimbombi, E., Barros, F., Sun, D., Liu, J., Sue, H.J., Sherman, P., Dunne, P. and Wright, A.O. Effect of Oxygen-absorbing packaging on the shelf life of a liquid-based component of military operational rations. *J. Food Sci*. 2009, 74, 167–176.
- Gomez-Estaca, J., De Lacey, A.L., Gomez-Guillien, M.C., Lopez-Caballero, M.E. and Montero, P. Antimicrobial activity of composite edible films based on fish gelatin and chitosan incorporated with clove essential oil. J. Aquat. *Food Prod. Tech.*, 2009, *18*, 46–52.
- Granda-Restrepo, D.M., Soto-Valdez, H., Peralta, E., Troncoso-Rojas, R., Vallejo-Cordoba, B., Gamez-Meza, N. and Graciano-Verdugo, A.Z. Migration of alpha-tocopherol from an active multilayer film into whole milk powder. *Food Res. Int.*, 2009, *42*, 1396–1402.
- Gutierrez, L., Escudero, A., Batlle, R. and Nerin, C. Effect of mixed antimicrobial agents and flavors in active packaging films. *J. Agric. Food Chem.*, 2009, *57*, 8564–8571.

- Guynot, M.E., Sanchis, V., Ramos, A.J. and Marin, S. Mold-free shelf-life extension of bakery products by active packaging. *J. Food Sci.*, 2003, *68*, 2547–2552.
- Goddard, N.R.D., Kemp, R.M.J and Lane, R., An overview of smart technology, Packaging Technology and Science, 1997, 10, 129-143.
- Kerry, J.P., O‟Grady, M.N. and Hogan, S.A. Past, current and potential utilisation of active and intelligent packaging systems for meat and muscle-based products: A review. *Meat Sci.* 2006, 74, 113–130.
- Llorens, A., Lloret, E., Picouet, P.A., Trbojevich, R and Fernandez, A. (2011). Metallicbased
- micro and nanocomposites in food contact materials and active food packaging. Trends in Food Science & Technology, 1-11. doi:10.1016/j.tifs.2011.10.001
- Labuza, T.P. and Breene, W.M. (1989) Applications of active packaging for improvement of shelf-life and nutritional quality of fresh and extended shelf-life foods. Journal of Food Processing and Preservation;1989; 13, 1–69.
- Lee, D.S., Yam, K.L. and Piergiovanni, L. Active and Intelligent packaging. *Food Packaging Sci. Technol.* 2010, 1, 445 – 473.
- Mexis, S.F., Badeka, A.V. and Kontominas, M.G. Quality evaluation of raw ground almond kernels (*Prunus dulcis*): Effect of active and modified atmosphere packaging, container oxygen barrier and storage conditions. *Innov. Food Sci. Emerg*. 2009, *10*, 580–589.
- Mexis, S.F and Kontominas, M.G. (2010). Effect of oxygen absorber, nitrogen flushing, packaging material oxygen transmission rate and storage conditions on quality retention of raw whole unpeeled almond kernels (Prunus dulcis). LWT - Food Science and Technology, 43: 1-11.
- Mexis, S.F., Badeka, A.V., Riganakos, K.A and Kontominas, M.G. (2010). Effect of active and modified atmosphere packaging on quality retention of dark chocolate with hazelnuts. Innovative Food Science and Emerging Technologies, 11: 177-186.
- Moraes, A.R., Gouvela, L.R., Soares, N.F., Santos, M.D. and Goncalvesi, M.C. Development and evaluation of antimicrobial film on butter conservation. *Ciencia Tecnol. Alime.* 2007, *27*, 33–36.
- Ooraikul, B. (1991). Modified atmosphere packaging of bakery products. In B. Oaraikul, & M. E. Stiles (Eds.), Modified atmosphere packaging of foods. London: Ellis Horwood. 49-117.
- Rice, J. Fighting moisture – desiccant sachets poised for expanded usage. Food Processing, 63(8); 1994, 46–48.
- Rooney, M.L. (ed.) (1995) Active Food Packaging, Chapman & Hall, London, UK.
- Rooney, M.L. Oxygen scavenging plastics for retention of food quality, in Proceedings of
- Conference on ‘Advances in Plastics – Materials and Processing Technology for Packaging’,
- Pira International, Leatherhead, Surrey, UK; 1998, 25 February.
- Rooney, M.L Applications of ZERO2™ oxygen scavenging films for food and beverage products,in Proceedings of the ‘International Conference on Active and Intelligent Packaging’,Campden & Chorleywood Food Research Association, Chipping Campden, Glos., UK, 7–8,September.2000
- Rodríguez, A., Nerin, C. and Batlle, R. New cinnamon-based active paper packaging against *Rhizopusstolonifer* food spoilage. *J. Agric. Food Chem*. 2008, 56, 6364–6369.
- Smith, A.J., Poulston, S., Rowsell, L., Terry, L.A. and Anderson, J.A. A New palladium-based ethylene scavenger to control ethylene-induced ripening of climacteric fruit. *Platin. Met. Rev.* 2009, 53, 112–122.
- Terry, L.A., Ilkenhans, T., Poulston, S., Rowsell, L. and Smith, A.J. Development of new palladium-promoted ethylene scavenger. *Postharvest Biol. Technol*. 2007, 45, 214–220.
- Vermeiren, L., Devlieghere, F., van Beest, M., de Kruijf, N. and Debever, J. Developments in the active packaging of foods. *Trends Food Sci. Technol*. 1999, 10, 77–86.
- Vermeiren, L., Heirlings, L., Devlieghere, F and Debevere, J. (2003). Oxygen, ethylene and other scavengers. In R. Ahvenainen (Ed.), Novel food packaging techniques. USA:
- CRC Press. 5-49.
- Yingyuad, S., Ruamsin, S., Reekprkhon, D., Douglas, S., Pongamphai, S. and Siripatrawan, U. Effect of chitosan coating and vacuum packaging on the quality of refrigerated grilled pork. *Packag. Technol. Sci.* 2006, 19, 149–157.
- Zinoviadou, K.G., Koutsoumanis, K.P. and Biliaderis, C.G. Physical and thermo-mechanical properties of whey protein isolate films containing antimicrobials, and their effect against spoilage flora of fresh beef. *Food Hydrocolloids,* 2010, 24, 49–59.