SİDAS MEDYA
Akademik Gıda® / Academic Food Journal
ISSN Print: 1304-7582
http://www.academicfoodjournal.com

Akademik Gıda 9(4) (2011) 36-41

Review Paper / Derleme Makale

Effect of Packaging on the Quality and Shelf-life of Minimally Processed/Ready to Eat Foods

Zehra Ayhan

Mustafa Kemal University, Department of Food Engineering, Hatay, Turkey

Received (Geliş Tarihi): 06.07.2011, Accepted (Kabul Tarihi): 06.09.2011
✉ *Corresponding author (Yazışmalardan Sorumlu Yazar): zehra.ayhan@gmail.com (Z. Ayhan)*
✆ +90 326 245 5845- 1055 ☏ +90 326 245 5832

ABSTRACT

Ready-to-eat/use products are a rapidly growing sector in the market because of increased consumer demand for fresh, healthy, convenient and additive-free prepared products. However, especially freshly prepared food items are highly perishable and prone to major spoilage mechanisms of enzymatic discoloration, moisture loss and microbial growth. Good manufacturing practices along with appropriate packaging materials are required to control these spoilage mechanisms. Ready-to-eat or minimally processed food products and their packaging requirements should be examined under two categories: (1) respiring horticultural products like minimally processed fresh-cut fruits and vegetables and (2) non-respiring products like ready-to-eat/use products such as meat, dairy or other products. The former products require highly permeable packaging material to oxygen and carbon dioxide in order to provide gas equilibrium inside the package. The gas equilibrium could be established if the product respiratory characteristics match to film permeability. For this purpose, modified atmosphere packaging (MAP) is used extensively to keep the product quality and increase the shelf-life. The key for successful MAP of freshly prepared produce is to use packaging film of correct permeability so as to establish optimum equilibrium atmosphere of 3-10% O_2 and 3-10% CO_2. For non-respiring ready-to-eat products, barrier packaging material is required to increase their shelf-life, and vacuum packaging, modified atmosphere packaging or active packaging technologies or their combination can be applied using multilayered plastic packaging materials with low permeability of especially oxygen and moisture. Nanomaterials with improved barrier properties can be an alternative to multilayered plastics to improve food quality and increase shelf-life.

Keywords: Ready-to-eat, Minimal processing, Packaging, Modified atmosphere packaging, Nanomaterials

Az İşlenmiş-Tüketime Hazır Gıdaların Kalite ve Raf Ömrüne Ambalajın Etkisi

ÖZET

Taze, sağlıklı, kullanımı kolay ve katkısız hazır gıdalara tüketici talebinin artması nedeniyle son yıllarda tüketime/kullanıma hazır gıdalar marketlerde hızla büyüyen bir sektör olmaya başlamıştır. Ancak özellikle işlenmiş taze ürünler oldukça kolay bozulur niteliktedir ve enzimatik renk değişimi, nem kaybı ve mikrobiyal üreme gibi ana bozulma mekanizmalarına maruz kalırlar. Bu bozulma mekanizmalarını kontrol etmek için ambalajlama sistemlerinin ve malzemelerinin doğru kullanımı ile birlikte iyi üretim uygulamaları zorunludur. Tüketime hazır veya az işlenmiş ürünler ve bunların ambalaj gereksinimleri iki kategori altında incelenmelidir: (1) az işlenmiş taze-kesilmiş meyve ve sebzeler (solunum yapan bahçe ürünleri), (2) tüketime/kullanıma hazır et ve süt ürünleri veya diğer ürünler (solunum yapmayan ürünler). Birinci grup ürünler ambalaj içinde gaz dengesinin sağlanması için oksijen ve karbondioksit geçirgenliği yüksek malzemelere ihtiyaç duyarlar. Eğer ürünün solunum karakteristikleri ile ambalaj malzemesinin geçirgenliği uyumlu ise gaz dengesi sağlanabilmektedir. Bu amaçla, ürün kalitesini sağlamak ve raf ömrünü uzatmak için modifiye atmosfer paketleme (MAP) tekniği yaygın olarak kullanılır. İşlenmiş taze ürünlerin modifiye atmosferde başarılı olarak paketlenmesindeki anahtar uygun geçirgenliğe sahip ambalaj filminin kullanımı ile optimum gaz atmosferi olan %3-10 O_2 ve %3-10 CO_2 oranlarının sağlanmasıdır. İkinci grup ürünlerde ise (solunum yapmayan tüketime hazır ürünler) raf ömrünü uzatmak için bariyerli ambalaj materyalleri gerekmektedir. Bu amaçla özellikle oksijen ve nem geçirgenliği düşük çok katlı ambalaj malzemeleri kullanılarak vakumlu ambalajlama, modifiye atmosfer paketleme veya aktif ambalajlama teknolojileri veya bunların kombinasyonu uygulanabilir. Gıda kalitesini geliştirmek ve raf ömrünü uzatmak için bariyer özellikleri geliştirilmiş nanomalzemeler de çok katlı malzemelere alternatif olabilir.

Anahtar Kelimeler: Tüketime/kullanıma hazır gıdalar, Az işlenmiş, Ambalajlama, Modifiye atmosfer paketleme, Nanomalzemeler

INTRODUCTION

Minimally processed and/or ready-to-eat/use food products have become popular due to their convenience, high value, unique sensory characteristics, and health benefits. Consumers demand safe, nutritious and ready-to-eat/use food products. Especially minimally processed or fresh-cut products are becoming rapidly growing sector of the horticultural industry [1]. Minimal processing has been defined as the handling preparation, packaging and distribution of agricultural commodities in a fresh like state, and may include processes such as dicing, peeling, trimming, slicing and curing [2]. Many terms are applied to fruits and vegetables cleaned and prepared in fresh form: lightly processed, minimally processed, prepared, precut, fresh-processed, and partially processed etc. The term fresh-cut is widely used for these products [3].

However, the quality of minimally processed produce rapidly changes during storage because of biological processes such as respiration, ripening and senescence [4, 5] The continuous respiration and metabolism of minimally processed fruits can cause significant changes in the textural, color and flavor qualities [5,6] Minimal processing may also increase microbial spoilage of fruit through transfer of skin microflora to fruit flesh where microorganisms can grow rapidly [7] The major factors responsible for extending the shelf-life of fruits and vegetables include careful harvest at optimum maturity and food sanitation. When these are properly practiced, the implementation of optimum storage conditions (storage temperature and relative humidity) through appropriate packaging can be quite effective, maximizing product shelf-life and quality [8].

Increase in market of ready to eat foods requires new preservation strategies to prolong the shelf-life of minimally processed food along with high quality and safety. After lowering the storage temperature, modified atmosphere packaging is considered to be the most effective method extending shelf-life of fresh and minimally processed produce. For nonrespiring products like ready to eat/use meat, bakery and dairy products, MAP, active packaging, vacuum packaging or the combination could be applied to keep quality and extend the shelf-life.

MODIFIED ATMOSPHERE PACKAGING (MAP) / VACUUM PACKAGING

The basic concept of the MAP is the replacement of the air in a package headspace with a specific gas or gas mixture. MAP has become a widely used food preservation technique especially for fresh-cut fruits and vegetables to extend shelf-life by reducing water loss because of high relative humidity within MAP; inhibition of cut-surface browning by low O_2 and high CO_2; lowering respiration rates and ethylene biosynthesis by low O_2 and high CO_2; delayed tissue softening and retarded microbial growth [9, 10]. Therefore, MAP is suggested to extend the storage life of fruits and vegetables by controlling respiration rate, senescence and ripening by providing low oxygen and high carbon dioxide levels in food packaging [11, 12].

There are two types of MAP-passive and active. Passive MAP involves placing produce in a gas permeable package, sealing the package and allowing produce respiration to reduce oxygen and increase carbon dioxide in the package to desired steady-state equilibrium [13]. In active MAP, the O_2 and CO_2 concentrations are modified initially and changes dynamically depending on the respiration rate of commodities and the permeability of the film surrounding the produce [14, 15]. Passive MAP is applied only to fruits and vegetables. However, active MAP could be applied to all kind of food products.

Packaging under appropriate atmosphere conditions reduced respiration and decreased ethylene production, inhibited or delayed enzymatic reactions, alleviated physiological disorders and preserved the product from quality losses [1, 14 16, 17]. The benefits of modified atmosphere packaging have been extensively studied in extending shelf-life of many fruits and vegetables. The application of MAP limited the microbial growth and enhanced the quality of strawberries, [18] fresh cut mangoes and pineapples [19], segmented orange, grapefruits [20, 21] and pomegranate arils [22]. Soliva-Fortuny and Martin-Bellaso reported that reduced levels of O_2 combined with appropriate permeability of plastic package extended the microbiological shelf-life of fresh cut pears for almost 3 weeks under refrigerated storage [1]. However, packages with low permeability in combination with low O_2 atmospheres can stimulate the growth of anaerobic spoilage or pathogenic microorganisms [17].

Some researchers suggested the use of super atmospheric O_2 concentrations ranging from 30 to 100 kPa. It is claimed that elevated O_2 atmospheres control microbiological growth inhibit enzymatic discoloration and undesirable moisture and odor losses [23]. Jacxsens et al [24] reported that high O_2 atmospheres (>70% O_2) were found to be effective in inhibiting enzymatic browning of mushroom slices, grated celeriac and shredded chicory endive. However, concentrations above 80 kPa may cause pyhtotoxicity. Some authors reported that super atmospheric concentrations are more effective against microorganisms when used with high CO_2 levels of 15–20 kPa. High CO_2 atmospheres also inhibited most aerobic microorganisms especially gram-negative bacteria and moulds. However, the use of high CO_2 concentrations was reported to induce tissue breakdown and formation of large amounts of exudates for fresh-cut apples [16]. High carbon dioxide may also cause undesirable off flavor formation. High oxygen atmosphere was suggested for some specific types of ready-to-eat vegetables sensitive to enzymatic browning and spoilage by yeasts as an alternative to low oxygen modified atmosphere [24].

The success of MAP depends on an achievement of a balance between minimally processed product respiration rate and film permeability to maintain an acceptable equilibrium atmosphere within the package which is important for delaying ripening/ maturation/ senescence and thus, extending the product shelf-life. Achievement of this goal is dependent on product and package parameters as following [13]:

Product factors:

1. Respiration rate of the product at the seleceted storage temperature
2. Respiratory quotient of the product at the selected storage temperature
3. Mass of the product to be placed inside the package (or free volume inside the package)
4. Oxygen and carbon dioxide concentrations necessary to achieve optimum reduction of product aerobic respiration rate

Packaging film factors:

1. Oxygen, carbon dioxide and water vapor permeability of selected polymeric packaging materials at the selected storage temperature per unit thickness of material
2. Effect of relative humidity on film permeability to oxygen and carbon dioxide
3. Total surface area of the sealed package
4. Seal integrity of the package
5. Abuse resistance of the packaging film

There are many researches on polymeric and composite films with the aim of maintaining a favorable modified atmosphere in the package. The favorable atmosphere depends on the permeability of the film to various gases and on the metabolism rate of the fresh product. The differences between permeation and the metabolism rate could be overcome by using perforated films. The use of perforated films provides holding a modified atmosphere and allowing enough oxygen to partially satisfy the metabolic processes [25]. Microperforation technology depends on numerous, smaller and precise holes in the range of 50-60 µm in diameter for delivering the targeted atmosphere. The number of microperforations designed for any specific product depends on product's respiration rate, the desired balance between oxygen and carbon dioxide in the package, the diameter of holes, thickness and permeability of the packaging material [26].

The size and shape are two important attributes of perforated films which should be specific to product to be packaged [25]. It was reported that no stationary conditions compatible with any MA can be found for continuous film, however, with perforated film it is possible to find a stationary state where a constant MA is maintained inside the pack [25].

Recently developed, microperforated films with very high gas transmission rates are now commercially available and used for maintaining aerobic equilibrium modified atmosphere (EMA) (e.g. 5-15 %O_2 and 5-15 CO_2) for highly respiring produce such as broccoli, cauliflower, carrot, mushroom and spinach. However, microperforated films are relatively expensive, permit moisture and odor losses and may allow for the ingress of microorganisms into the sealed package during wet handling situations [27].

For nonrespiring products such as ready to eat/use meat products, the basic concept of MAP is to apply selected gas mixture to keep the initial gas concentrations inside the package during storage. For this reason, barrier materials with low O_2 and water vapor permeability are selected. Since these types of products are sensitive to oxidation, no oxygen in case of vaccum packaging or low oxygen in case of MAP should be applied. Multilayered materials or nanomaterials with high barrier properties should be selected to package this type of food products which require longer shelf-life than fruits and vegetables.

Vacuum packaging is the simplest method to modify the internal atmosphere. Product is placed in a pack made of film with low oxygen permeability, air is evacuated and the package is sealed. Vaccum packaging is extensively used for cured meat products, hard cheeses and ground coffee. This packaging is not suitable for soft products or bakery products since the vacuum process results in irreversible deformation of the product [28].

There are 3 packaging categories of MP products: consumer or end-products user packaging, transport packaging and unit load packaging. Unit packaging includes (1) sealed polymeric film bags, (2) rigid or semirigid plastic trays sealed across the top with polymeric films, and (3) overwrapped trays [13].

Modified atmosphere packaging of MP produce using active or passive techniques require appropriate selection of polymeric packaging materials with appropriate permeability of O_2, CO_2 and water vapor. Polymeric films with potential use in MAP of MP produce include LDPE, LLDPE, HDPE, PP, PVE, PS and EVA copolymers, perforated/microperforated PE and PP. Polymeric films selected for MAP should be six or more times more permeable to CO_2 than to O_2. [13].

This technology seems straightforward since it uses permeable film and the product respiration rate at a specific temperature to alter the concentration of oxygen and carbon dioxide around the product. However, the complexity of this packaging system is always underestimated [29]. In the new MAP era, it is necessary to show that MAP does not only deal with gas mixture and films. The new thought is to incorporate the functional intrinsic and extrinsic elements to solve the food safety issue proactively and to minimize or eliminate food safety risks. The intrinsic elements are directly related to packaging such as intelligent or active packaging. The extrinsic elements include the processing environment which will impact the packaging [30].

ACTIVE PACKAGING

Active packaging involves the manipulation of the environment in the package to enhance food quality and safety, and thus, to extend the shelf-life. Active packaging systems can be classified into active-scavenging systems (absorbers) and active-releasing systems (emitters) [31, 32]. The active packaging systems are oxygen and ethylene scavengers, moisture absorbers, ethanol and carbon dioxide emitters and anti-microbial releasing systems [33, 34, 35]. Fruits and vegetables under MAP could be especially combined with ethylene absorber and humidity regulators to increase the effectiveness of MAP. Antimicrobial releasing films could also be used in MAP of fruits and vegetables to control surface microorganisms.

An ethylene scavenger system involves the inclusion of a small sachet which contains an appropriate scavenger in the package. The sachet material is highly permeable to ethylene which diffuses through the sachet. The reacting component inside the sachet is commonly potassium permanganate which oxidizes or inactivates ethylene [33]. Other ethylene removing system is based on the use of finely dispersed minerals (zeolite, active carbon, pumice etc.) to absorb ethylene. These minerals could be incorporated in polyethylene bags which are used to package fresh fruits and vegetables [32]. These minerals not only absorb ethylene but also alter the permeability of the film so that ethylene and CO_2 diffuse more rapidly and O_2 enters more readily than through pure polyethylene [32]. Ethylene absorbers can especially extend the shelf-life of climacteric fruits such as apples, kiwi fruit, apricot, bananas, mango, cucumber, tomato and avocados, and vegetables such as carrots, potatoes and asparagus [32].

Excess CO_2 could be removed by using CO_2-permeable pack placed inside a MAP. CO_2 absorbers include $Ca(OH)_2$, activated charcoal and magnesium oxide. The amount of CO_2 absorbent required depends on the excess CO_2 level, the desired CO_2 level and the shelf-life period [13].

Moisture regulators can prevent the growth of yeast and bacteria at high a_w foods like minimally processed fruits and vegetables [32]. Shirazi and Cameron [40] studied the humidity-controlling capacity of dry sorbitol, xylitol, NaCl, KCl, $CaCl_2$ enclosed in polyethylene pouches in modified atmosphere packaged tomatoes. The study showed that the storage life of tomatoes was extended from 5 days to 15-17 days at 20℃ with the use of sodium chloride due to prevention of surface mold development. The control of excessive water can be carried out by application of drip absorbent sheets which enclose a layer of superabsorbent polymer such as polyacrylate salts or cellulose fibers. However, this system can be used for fish, meat and poultry packaging. Another application to control excess moisture in packaged food is to use humectants such as propylene glycol which could be placed between two plastic films. For horticultural products, humidity-buffering systems are needed [32].

For non-respiring products, vacuum packaging or MAP could be combined with active packaging systems. Antimicrobial films could be used in vacuum packaging where products need surface contact for microbial activity. MAP could be combined with oxygen scavengers to limit the oxygen concentration inside the package. Materials with antimicrobial or antioxidant properties could be used in MAP packaging to enhance food quality and safety. There is a great interest in developing MAP of consumer-ready meat products. Some commercial applications of MAP in consumer-ready products are found in high-premium markets [36].

PACKAGING USING NANOMATERIALS

Nowadays, multilayered packaging materials with low gas permeability are extensively used in ready-to-eat meat, dairy and other products to assure food quality, safety and required shelf-life due to their barrier properties. It is important to choose material low in oxygen and water vapor transmission rates. For this purpose, barrier materials such as PVdC or EVOH containing materials are preferred. However, laminated materials especially with PVdC and EVOH are highly expensive and these materials are not eco-friendly. Due to complex production techniques, high cost and non recyclable nature of the multilayered materials, nanomaterials with improved barrier properties could be a good alternative to multilayered materials.

Many studies have focused on preparation and characterization of nanocomposites. However, there has been limited research published on the potential use of nanomaterials in packaging of foods including minimally processed foods. A study showed that isotactic polypropylene filled with innovative calcium carbonate nanoparticles was able to preserve minimally processed apple slices for up to 10 days, limiting oxidation and microbiological growth [37]. However, it might be very risky to use nanomaterials with low gas permeability for respiring products such as fruits and vegetables.

Nanocomposites including antimicrobials could be useful for products susceptible to surface spoilage such as cheese, bakery goods and sliced meat products vacuum packed or film wrapped so that most of the product surface is in contact with the packaging [38]. Materials containing nanosilver as antimicrobial agent could be used in fruits and vegetables to extend the shelf-life since silver absorbs and decomposes ethylene. It was reported that a coating containing nanosilver was effective in decreasing microbial growth and increasing shelf-life of asparagus [39].

CONCLUSIONS

For respiring MP products, highly permeable packaging materials to O_2 and CO_2 are required to provide gas equilibrium inside the package. The key for successful MAP of fresh prepared produce is to use packaging film of correct permeability so as to establish optimal equilibrium atmosphere of 3-10% O_2 and 3-10% CO_2. For non respiring ready to eat products, barrier packaging to O_2 and water vapor is required to keep quality and increase the shelf-life. MAP, active packaging or vacuum packaging or the combination could be applied using multilayered plastic packaging materials with low permeability of O_2 and moisture. Nanomaterials with improved barrier properties could be an alternative to multilayered plastics to improve food quality and increase shelf-life of nonrespiring MP products. The best chance of success for MAP could be achieved by combination with active and intelligent packaging technologies. This technique can be integrated with active or interactive packaging to improve the control over the package atmosphere to achieve superior product quality and safety. However, the complexity of the integrated system should be considered especially for the respiring foods.

REFERENCES

[1] Soliva-Fortuny, R.C., Martin-Bellaso, O., 2003. Microbiological and biochemical changes in minimally processed fresh cut pears. *Eur. Food Res. Technol.* 217: 4-9.

[2] Shewfelt, R.L., 1987. Quality of minimally processed fruits and vegetables. *J. Food Qual.* 10: 143-156.

[3] Cantwell, M., 1997. Introduction and information sources. In *Fresh-cut-products: Maintaining quality and safety*. Postharvest Horticulture Series 10, Section 1-1, University of California, Davis.

[4] Labuza, T.P., Brene, W.M., 1989. Applications of 'active packaging' for improvement of shelf-life and nutritional quality of fresh and extended shelf-life foods. *J. Food Process. Preserv.* 13: 1-69.

[5] Liu, C.L., Hsu, C.K., Hsu, M.M., 2007. Improving the quality of fresh-cut pineapples with ascorbic acid/sucrose pretreatment and modified atmosphere packaging. *Pack. Tech. Sci.* 20(5): 337-343.

[6] O'Connor-Show, R.E., Roberts, R., Ford, A.L., Nottingham, S.M., 1994. Shelf-life of minimally processed honeydew, kiwifruit, papaya, pineapple and cantaloupe. *J. Food Sci.* 59(6): 1202–1206.

[7] Bracket, R.E., 1992. Shelf stability and safety of fresh produce as influenced by sanitation and disinfection. *J. Food Protec.* 55: 808-814.

[8] Farber, J.N., Harris, L.J., Parish, M.E., Beuchat, L.R., Suslow, T.V., Gorney, J.R., Garret, E.H., Butsa, F.F., 2003. Microbiological safety of controlled atmosphere and modified atmosphere packaging of fresh and freshcut produce. *Comp. Rev. Food Sci. Food Safety* 2: 142-160.

[9] Gorny, J.R., 2003. A summary of CA and MA requirements and recommendations for fresh-cut (minimally processed) fruits and vegetables. *Acta Hort.* 600: 609-614.

[10] Wang, Y.C., 2006. Biochemical basis of the effects of modified and controlled atmospheres. *Stewart Postharv. Rev.* 5(8): 1-4.

[11] Zagory, D., Kader, A.A., 1998. Modified atmosphere packaging of fresh produce. *Food Technol.* 42(9): 70-77.

[12] Gunes, G., Lee, C.Y., 1997. Color of minimally processed potatoes as affected by modified atmosphere packaging and antibrowning agents. *J. Food Sci.* 62(3): 572-582.

[13] Schlimme, D.V., Rooney, M.L., 1994. Packaging of minimally processed fruits and vegetables. In Minimally Processed Refrigerated Fruits and Vegetables, edited by R. C. Wiley. Chapman & Hall, New York. 135-182p.

[14] Erkan, M., Wang, C.Y. 2006. Modified and controlled storage of subtropical crops. *Postharv. Biol. Technol.* 5(4): 1-8.

[15] Chauhan, O.P., Raju, P.S., Dasgupta, D.K., Bawa, A.S., 2006. Instrumental textural changes in banana (var. Pachbale) during ripening under active and passive modified atmosphere. *Int. J. Food Prop.* 9(2): 237-253.

[16] Soliva-Fortuny, R.C., Martin-Bellaso, O., 2003. New advances in extending the shelf-life of fresh cut fruits: A Review. *Trends Food Sci. Tech.* 14: 341-353.

[17] Martin-Bellaso, O., Soliva-Fortuny, R.J., 2006. Effect of modified atmosphere packaging on the quality of fresh cut fruits. *Postharv. Biol. Technol.* 1(3): 1-8.

[18] Garcia, J.M., Media, R.J., Olias, J.M., 1998. Quality of strawberries automatically packed in different plastic films. *J. Food Sci.* 63(6): 1037-1041.

[19] Martinez-Ferrer, M., Harper, C., Perez-Munaz, F., Chaparro, M., 2002. Modified atmosphere packaging of minimally processed mango and pineapple fruits. *J. Food Sci.* 67(9): 3365-3371.

[20] Karacay, E., Ayhan, Z., 2010. Microbial, physical, chemical and sensory qualities of minimally processed and modified atmosphere packaged "Ready to-Eat" orange segments. *Int. J. Food Prop.* 13(5): 960-971.

[21] Karacay, E., Ayhan, Z., 2010. Physiological, physical, chemical characteristics and sensory evaluation of minimally processed grapefruit segments packaged under modified atmosphere. *J. Agric. Sci.* 16: 129-138.

[22] Ayhan, Z., Esturk, O., 2009. Overall quality and shelf-life of minimally processed and modified atmoshere packaged "Ready-to Eat" pomegranate arils. *J. Food Sci.* 74(5): C399-C405.

[23] Kader, A.A., Ben-Yehoshua, S., 2000. Effects of super atmospheric oxygen levels on postharvest

physiology and quality of fresh fruits and vegetables. *Postharv. Biol. Technol.* 20: 1-13.

[24] Jacxsens, L., Devlieghere, F., der Sten, C.V., Debevere, J., 2001. Effect of high oxygen modified atmosphere packaging on microbial growth and sensorial qualities of fresh-cut produce. *Int. J. Food Microbiol.* 71: 197-210.

[25] Zanderighi, L., 2001. How to design perforated polymeric films for modified atmopshere packs (MAP). *Pack. Technol. Sci.* 14: 253-266.

[26] Greengras, J., 1999. Packaging materials for MAP food in *Principles and Applications of Modified Atmosphere Packaging of Foods*, edited by B.A. Blakistone, Apsen Publication, Maryland. 63-101p.

[27] Day, B.P.F., 2003. Novel MAP applications for fresh-prepared produce. In Novel Food packaging Techniques, edited by R. Ahvenainen, Woodhead Publishing Limited, England. 189-207p.

[28] Blakistone, B.A., 1999. Introduction. In Principles and Applications of Modified Atmosphere Packaging of Foods, edited by B.A. Blakistone, Apsen Publication, Maryland. 1-13p.

[29] Jobling, J., 2001. Modified atmosphere packaging: not as simple as it seems. www.postharvest.com.au

[30] Yuan, J.T.C., 2003. Modified atmosphere packaging for shelf-life extension. In Microbial Safety of Minimally *Processed Foods*, edited by J.S. Novak, G.M. Sapers and V.K. Jureja, CRC Press, New York. 205- 217p.

[31] Smith, J.P., Hoshino, J. Abe, Y., 1995. Interactive packaging involving sachet technology in *Active Food* Packaging, edited by M.L. Rooney, Blackie Academic Professional, London. 143- 173p.

[32] De Kruijf, N., Van Beest, M., Rijk, R., Sipilainen-Malm, T., Losada, P.P., De Meulenaer, B., 2002. Active and intelligent packaging: applications and regulatory aspects. *Food Additiv. Cont.* 19: 144-162.

[33] Floros, J.D., L. L. Dock, L.L., Han, J.H., 1997. Active packaging technologies and applications. *Food Cosmetics Drug Pack.* 20: 10-17.

[34] Vermeiren, L., Devlieghere, F., Van Beest, M., De Kruijf, N., Debevere, J., 1999. Developments in the active packaging of foods. *Trends Food Sci. Tech.* 10(3): 77-86.

[35] Powers, T., Calvo, W.J., 2003. Moisture regulation. In Novel Food Packaging Techniques, edited by R. Ahvenainen, Woodhead Publishing Limited, England. 172-185p.

[36] Jayas, D.S., Jeyamkondan, S., 2002. Modified atmosphere storage of grains meats fruits and vegetables. *Biosys. Eng.* 82(3): 235-251.

[37] Avella, M., Bruno, G., Errico, M.E., Gentile, G., Piciocchi, N., Sorrentino, A., Volpe, M.G., 2007. Innovative packaging for minimally processed fruits. *Pack. Tech. Sci.* 20: 325-335.

[38] Anonymous, 2008. Nanotechnology in packaging: a revolution in waiting. *Food Eng. Ingred.* 33(3): 6-9.

[39] Azeredo, H.M.C., 2009. Nanocomposites for food packaging applications. *Food Res. Int.* 49: 1240-1253.

[40] Shirazi, A., Cameron, A.C., *1992*. Controlling relative humidity in modified atmosphere packages of tomato fruit. *HortScience* 27:336-339.