Intl. J. Food. Ferment. Technol. 8(2): 153-159, December 2018

DOI: 10.30954/2277-9396.02.2018.4

REVIEW PAPER

Coating of Fruits and Vegetables based on Natural Sources: An Alternative to Synthetic Coating

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Paper No.: 216 **Received:** 09-06-2018 **Revised:** 24-09-2018 **Accepted:** 13-11-2018

ABSTRACT

In recent past years, a lot of research work has been done to develop innovative films and coatings for packaging of fruits and vegetables which improve their qualitative parameters during storage. Recently, researchers are focusing to design films and coatings based on biodegradable materials which would serve as covering to the food and reduce the hazards caused by use of plastics and by degrading biologically. The objectives behind the preparation of packaging such films and coatings is to reduce the loss of moisture, migration of gases and to extend the shelf life of the fruits and vegetables. This paper not only reviews introduction and need of coating but also provide the knowledge about types of coating on different fruits and vegetables. The main focus on the review is on the coating of fruits and vegetables based on natural sources.

Keywords: Coating, fruits, vegetables, natural sources, shelf-life

Fruits and vegetables are important part of daily diet and in recent years, they are in high demand from most of the population. They are rich in vitamins, essential minerals, antioxidants, bioflavonoids, dietary fibers and flavor compounds because of which they get exposed to abiotic and biotic adversities. Due to perishable nature of fruits and vegetables they are easily attacked by microorganisms and insects; respiration and transpiration processes leads to faster deterioration of the quality (Tiwari *et al.* 2014). In addition to this, spoilage of fruits and vegetables is caused due to external and internal factors. Environmental factors mainly O_2, CO_2, ethylene gas, temperature and other stress factors are categorized under external factors while the internal factors include the species, cultivar and stage of harvesting (Kluge *et al.* 2002). Also, the skin of fruits and vegetables is responsible for contamination of the flesh which increases the possibilities of the spoilage and results in biochemical deterioration such as browning, off-flavour and texture breakdown. This decreases the quality of fruits and vegetables and consumers get exposed to risk due to the presence of pathogenic microbes (Harris *et al.* 2003). Principal factors which determine the quality of fruits and vegetables include texture, colour, appearance, flavor, nutritional value and microbial safety contribute to the marketability. Deterioration of fruits and vegetables due to post-harvest losses is a serious problem for which finding a solution is very necessary. Spoilage of fruits and vegetables results in a decrease in commercial value and lots of damages are caused to the producer. According to report given by Food and Agriculture Organization (FAO), half of the fruits and vegetables are lost and wasted every year because of storage problems, retail, transportation and post harvest processing. The report also reveals that the loss and wastage of fruits and vegetables in Southeast Asia and South Asia is maximum i.e. almost 20% during packaging and transformation. In India, about 44.6% vegetables, 34% fruits and 40% combined fruits and vegetables are unable to be sold by farmers (Pandey, 2018).

Owing to big losses in harvested fruits and vegetable, farmers are facing income losses all over the world. Hence, there is a need to adopt advance techniques and post-harvest processing to reduce these losses which are quantitative and qualitative as well.

PREVENTIVE MEASURES FOR SPOILAGE OF FRUITS AND VEGETABLES

To prevent the spoilage and to prolong the shelf life of fruits and vegetables, use of various processes such as low temperature processes, modified atmospheric packaging, irradiation and coating have been done (Xanthopoulos *et al.* 2012; Castagna *et al.* 2013; Sanudo *et al.* 2009). It has been found that different preservation techniques including cold storage, UV irradiation, modified atmospheric packaging and ozonization are used to reduce the spoilage, increase shelf life and retain the nutritional value of fresh fruits (Duan *et al.* 2011). Because of economical cost and reduction in nutrients due to some preservation techniques, other preventive measures also have been found by researchers. Edible films and coatings is one of them which is gradually developing day by day and have proven to improve shelf life of fruits and vegetables by many workers.

EDIBLE COATING AND ITS TYPES

Thin layer of material which can be consumed and provide a barrier to oxygen, moisture and solute movement and microorganisms of an external source for food is defined as edible coating. It increases the shelf life by reducing the loss in water content and migration of solutes, exchange of gases, respiration and rates of oxidative reactions as well as it decreases physiological disorders on fresh-cut fruits by offering the semipermeable barrier (Baldwin *et al.* 1996). Guilbert *et al.* (2005) defined edible coating as a thin layer of material that covers surface of the food and can be eaten as a part of the whole product. Therefore, composition of edible coatings must fulfill the regulations that apply to the related food product. Hence, the edible coatings are defined by European Directive (Directive 95/2/CE; Directive 98/2/CE) and the US Code of Federal Regualtion (FDA 21 CFR 1722006).

Different methods for the application of coating includes dipping, spraying, brushing and panning followed by drying. Preparation of edible film is carried out by using hydrocolloids, proteins, polysaccharides, lipids and composites (Donhowe and Fennema, 1993). An edible coating has shown to be a preservation technique which preserves fruit plumpness, fresh appearance and hardness as well as gives the shiny surface to fruits, therefore increases the commercial value of fruits (Xu and Chen, 2003). Traditionally, food corporations use polymeric films (polyethylene PE, plastic PP, poly-styrene PS) to pack fruits and vegetables owing to their massive availability at a relatively low price and their good mechanical properties, a barrier to oxygen, carbon dioxide (Siracusa *et al.* 2008). But the major use of synthetic packaging films has resulted to serious ecological issues due to their total non-biodegradability. Thus, biodegradability is not solely a functional demand however, conjointly a very important environmental attribute. Renewable raw materials like starch and bio-derived monomers can be used as bio-based packaging fruits and vegetables by replacing petrochemical-based materials with biodegradable is increasing day by day (Tharanathan, 2003).

Edible films and coatings have got significant consideration in recent years on account of their benefits over synthetic films. The principal advantage of edible films over conventional synthetics is that they can be eaten with the package. There is no issue of disposal of the package even if the package has not been eaten, it would not take part in environmental pollution. These films are prepared by using renewable, edible ingredients and therefore are easy and faster to break down as compared to plastic.

Table 1: Different lipid coating materials

Produce	Coatings Types	Effect on Produce	References
Guava	Carnauba wax	Delayed ripening and reduction in water loss and decay incidence. TSS, total titratable acidity, and ascorbic acid less affected.	Jacomino *et al.* 2003; Kore and Kabir, 2011
	Semperfresh and A. vera gel (1:1 or 100%)	Reduced fruit aroma volatile development. Slightly delayed fruit ripening.	Dang, 2008
Apple	Wax, oil	Increased shelf-life	Sabir *et al.* 2004
	Paraffin wax + beeswax + soybean oil + CMC	Reduced level of soluble solids, titratable acidity and ascorbic acid loss; increased storage life up to 34 days	Torgul and Arslan, 2005
	Candelilla Wax	Improved shelf life, excellent antifungal barrier and inhibit growth of natural phytopathogenic fungal strains; and slow weight loss	Ochoa *et al.* 2011
Peach	Wax	Reduced rate of physico-chemical changes; retained the quality	Chaynika *et al.* 2005
Passion fruit	Carnauba wax	Reduced fresh matter loss percentage and increased relative water retention; Reduced level of peel percentage and pulp. Increased pulp/peel percentages	Mota *et al.* 2006
Pomegranate	Oil + starch	Decreased softening of arils, weight loss and % of browning index, loss of vitamin C, anthocyanin loss and delayed microbial spoilage	Oz and Ulukanli, 2012
Walnuts and Pine nuts	Whey protein isolate + Carnauba wax + Pea starch (PS)	Retarded oxidative and hydrolytic rancidity, improved smoothness and sensory characteristics	Mehyar *et al.* 2012
Huanghua pears	Shellac	Retaining texture (especially for brittleness); maintained higher POD activity and lowering activities of cell wall hydrolases such as PE, PG, and cellulose	Zhou *et al.* 2011
Tomato	Mineral oil wax	Preserving quality and extending the shelf life, reduced weight and firmness losses	Davila-Avina *et al.* 2011
Green pepper	Semperfresh	Retaining higher contents of Vit. 'C' and total 'chlorophyll'	Ozden and Bayindirli, 2002
Pointed gourd	Semperfresh	Reduced physiological loss in weight and shrinkage	Chakraborty *et al.* 2002
Mango	Carnauba Wax	Improved fruit quality characteristics including levels of fatty acids and aroma volatiles. Prevented fruit ripening, fruit firmness retained.	Dang, 2008

The films can improve the qualitative properties of packaged food even though they are containing different additives such as flavours, colours, sweetners (Bourtoom, 2008). Preparation of edible films and packages using natural waxes, resins and polysaccharides give an ideal packaging material as they can be eaten with the package. Renewable sources are used in making of such packaging materials whereas synthetic packaging is made up of paraffin, mineral oil, oxidized polyethylene and plastics which are manufactured from fossil fuels available in limited quantity (Baldwin, 1994). Taking into account, the demand for the healthier, safer, more natural and eco-friendly products have been developed recently as an alternative to synthetic waxes (Fresh Plaza, 2013). There are different types of coatings which based on natural sources like lipids, proteins and carbohydrates.

LIPID-BASED COATINGS

A group of hydrophobic compounds, which are neutral esters of glycerol and fatty acids are lipids.

Esters of long-chain monohydric alcohols and fatty acids known as "waxes", comes under lipids category (Hernandez, 1994). Coatings based on lipids (Table 1) known to be good barriers to moisture loss. It extends the shelf-life by preventing moisture loss and reducing the respiration. It improves appearance by giving a shiny product in fruits and vegetables.

PROTEIN BASED COATINGS

Sources of proteins used in edible coatings of plant-derived include corn zein, wheat gluten, soy protein, milk proteins and animal-derived proteins like collagen, keratin and gelatin (Zhang and Mittal, 2010). Different types of proteins that are used as coatings are given in Table 2.

CARBOHYDRATE-BASED COATINGS

Different types of polysaccharides are used to make edible coatings. Marine and agricultural plants and animals are generally used for the extraction of polymers to make the coatings. These coatings can be used to reduce the loss of moisture from food during the storage. Being hydrophilic in nature, polysaccharides, do not function well as physical moisture barriers. The approach by using which is they retard moisture loss by acting as a sacrificial moisture barrier to the surrounding so that the moisture content of the coated food can be maintained (Kester and Fennema, 1986). In addition to stopping moisture loss, some forms of polysaccharide films are less permeable to oxygen, that could assist to maintain the quality of foods. Some polysaccharides possess crystalline nature which causes processing and performance issues especially in terms of packaging of wet products. However, these polysaccharides make materials which possess impressive gas barrier properties. The commonly used polysaccharides for material production include cellulose, starch, gums, and chitosan. The linear structure of these polysaccharides include cellulose, amylose (a component of starch), and chitosan that offers toughness, flexiblility, transparency to their films, and makes them resistant to fats and oils. The

Table 2: Different protein based coatings and their impacts

Produce	Coating Type	Important finding	Reference
Apples	Whey protein + Gellan Gum	WPC-gellan coated fruits were rated highest for taste, glossiness, colour and overall acceptability and lowest loss in weight, no, better TSS and acidity content	Javanmard (2011)
Apples, potatoes, carrots, and onions	Soy protein isolate (SPI)	SPI coatings proved as a good moisture barrier and antioxidative property.	Shon J *et al.* (2011)
Kiwifruit	Rice Bran oil + Whey protein concentrate	Preserved colour, firmness, taste, and overall acceptability of the fruits, lowered increment in acidity and weight loss	Hassani *et al.* 2012
Cherry	Gelatine film	Lowest moisture loss	Lim *et al.* 2011
Apple	Carrageenan + whey protein Concentrate	Maintained the original colourduring storage without changes in sensory properties.	Lee *et al.* 2003
Mango	Galactomannans + collagen	Effective in less (O_2) consumption and (CO_2) production	Lima *et al.* 2010
Zucchini	Casein proteins	Reduced water loss	Avena-Bustillos *et al.* 1994
Potato	Whey protein + calcium caseinate	Delayed browning	Tien *et al.* 2001
Apple slices	Milk protein	Decreased oxidative browning and moisture loss	Krochta *et al.* 1994

Table 3: Different carbohydrate based coating materials and impacts

Produce	Coating Types	Effect on produce	References
Papaya	Carrageenan + carboxymethyl cellulose	The changes in weight loss, titratable acidity, total soluble solids delayed. Decaying percentage, sugar content, phenols, and ascorbic acid delayed	Vyas *et al.* (2013)
Orange	Hydroxypropylmethylcellulose (HPMC)	Extended shelf-life	Adetunji *et al.* (2012)
Sapota	Pectin (2%) Sodium alginate	Maintained organoleptic properties	Joslin *et al.* (2016)
Strawberry	Chitosan	Lowered moisture loss and delayed the changes in colour, titratable acidity and ascorbic acid content. Prevented flesh browning, and reduced membrane damage. Lowered rate of deterioration.	Milena *et al.* (2015)
Papaya	*Aloe vera* gel	Lowered Physiological loss in weight. Maintained ripening process and decaying and increased shelf-life.	Marpudi *et al.* 2011
Guava	Potato starch	pH, Titratable acidity and sugars, soluble and total pectin, firmness, and values of chlorophyll a and b remained unaffected	Boas *et al.* 2005
Cherry	*Aloe vera* gel	Loss of water and firmness prevented. Respiration rate and maturation development controlled. Delayed oxidative browning and lowered microorganism multiplication	Martinez-Romero *et al.* 2006
Pineapple	Chitosan	Extends shelf-life	Talens *et al.* 2012
Apple	*Aloe vera* gel	Delayed loss of total phenolics and ascorbic acid	Serrano *et al.* 2006

polysaccharides used in edible coating formulation discussed in Table 3.

CONCLUSION

The utilization of edible coatings and films as protective packaging techniques for the food industries has turned into a point of incredible intrigue on account of their potential for improving the shelf life of fruits and vegetables and maintaining quality attributes. These coatings inhibit the migration of water vapours, O_2, CO_2, aromas etc. They carry different food additives and retain the natural properties of food for longer time. However, coatings and films should be chosen for fruits and vegetables packaging as it offers lots of benefits over conventional packaging. Being biodegradable in nature it reduces the cost of packaging and health hazards which appear due to plastic packaging.

REFERENCES

Adetunji, C.O., Fawole, O.B., Arowora, K.A., Nwaubani, S.I., Ajayi, E.S., Oloke, J.K., Majolagbe, O.N., Ogundele, B.A., Aina, J.A. and Adetunji, J.B. 2012 Quality and Safety of *Citrus sinensis* Coated with Hydroxypropylmethylcellulose Edible Coatings Containing *Moringa oleifera* Extract Stored at Ambient Temperature. *Global Journal of Science Frontier Research Bio-Tech & Genetics*, **12**(5): 0975-5896.

Andrade, R.D., Skurtys, O. and Osorio, F.A. 2012. Atomizing spray systems for application of edible coatings. *Comprehen. Rev. Food Sci. Food Safe*, **11**(3): 323-337.

Avena-Bustillos, R.J., Krochta, J.M., Saltveit, M.E., Rojas-Villegas, R. and Sauceda-Perez, J.A. 1994. Optimization of edible coating formulations on zucchini to reduce water loss. *J. Food Eng*., **21**: 197-214.

Baldwin, E.A., Nesperos-Carriedo, M.O., Chen, X. and Hagenmaier, R.D. 1996. Improving storage life of cut apple and potato with edible coating; *Post-harvest Bio. Technol*., **9**: 151-163.

Baldwin, E.A. 1994 Edible coatings for fresh fruits and vegetables: past; present; and future; Edible Coatings and Films to Improve Food Quality (1. M. Krochta; E. A. Baldwin; and M. O. Nisperos Carriedo; eds.); *Technomic Publishing Company; Lancaster; PA*: 25.

Boas, B.V., Nunes, E.E., Silva, W.A., Boas, E.V., Siqueira, H.H. and Pereira, J. 2005. Post-harvest quality of 'Pedro Sato' guavas coated with potato starch film. *Rev. Bras. Armaz*., **301**: 91-96.

Bourtoom, T. 2008. Edible films and coatings: characteristics and properties Review. Article. *Int. Food Res. J*., **15**(3): 237-248.

Castagna, A., Chiavaro, E., Dall'asta, C., Rinaldi, M., Galaverna, G. and Ranieri, A. 2013. Effect of post-harvest UV-B irradiation on nutraceutical quality and physical properties of tomato fruits. *Food Chem*., **137**: 151-158.

Chakraborty, K., Ray, S.D. and Kabir, J. 2002. Influence of semperfresh coating on storage life of pointed gourd *Trichosanthes dioica Roxb. J. Inter.*, **6**: 486-489.

Chaynika, G., Thakur, K.S. and Kaushal, B.L. 2005. Effect of various post-harvest treatments on the storage quality of peach cv. July *Elberta. Acta Hort*., **696**: 509-517.

Dang, KH. 2008. Edible coatings influence fruit ripening; quality; and aroma biosynthesis in mango fruit. *J. Agric. Food Chem.*, **564**: 361-1370.

Debeaufort, F. and Voilley, A. 2009. Lipid-based edible films and coatings. In: Embuscado ME; Huber KC; editors. Edible films and coatings for food applications. *New York: Springer, pp.* 135-164.

Donhowe, I.G. and Fennema, O.R. 1993. The effects of plasticizers on crystallinity; permeability; and mechanical properties of methylcellulose films. *Journal of Food Processing and Preservation*, **17**: 247-257.

Duan, J., Wu, R., Bernadine, S. and Zhao, Y. 2011. Effect of edible coatings on the quality of fresh blueberries (Duke and Elliott) under commercial storage conditions. *Post-harvest Biol Tech*., **59**: 71-79.

Dávila-Aviña, J., Esteban de Jesús, Villa-Rodríguez, J., Cruz-Valenzuela, R., Rodríguez-Armenta, M., Espino-Díaz, M. and Ayala-Zavala, J.F. 2011. Effect of edible coatings; storage time and maturity stage on overall quality of tomato fruits. *Amer. J. Agric. Biol. Sci.*, **61**: 162-171.

Fresh Plaza. 2013. Spain: Naturcover; the new natural coating for stone fruit. Available at: http://www.freshplaza.com/news_detail.asp?id=106695

Guilbert, S., Gontard, N. and Cuq, B. 1995. Technology and application of edible protective films. *Packaging Technology and Science*, **8**: 339-346.

Harris, L.J., Farber, J.N., Beuchat, L.R., Paris, M.E., Suslow, T.V., Garrett, E.H. and Buster, F.F. 2003. Outbreak association with fresh produce; *Compre. Rev. Food Sc. F.* (Supplement); **2**(3): 78-141.

Hassani, F., Garousi, F. and Javanmard, M. 2012. Edible coating based on whey protein concentrate-rice bran oil to maintain the physical and chemical properties of the *kiwifruit Actinidia deliciosa. Trakia J. Sci.*, **101**: 26 34.

Hernandez, E. 1994 Edible coatings from lipids and resins; Edible Coatings and Films to Improve Food Quality (J. M. Krochta; E. A. Baldwin; and M. O. Nisperos-Carriedo; eds.); *Technomic Publishing Company; Lancaster*; *PA*:279.

Jacomino, A.P., Ojeda, R.M., Klude, R.A., Scarpare Filho, J.A. 2003. Post-harvest conservation of guavas through carnauba wax emulsion application. Rev. *Bra. Fruit*, **253**: 401-405.

Javanmard, M. 2011. Shelf-Life of Apples Coated with Whey Protein Concentrate- Gellan Gum Edible Coatings. *Journal of Food Biosciences and Technology*, **1**: 56 -62.

Joslin, M. and Athmaselvi, K. 2016. Polysaccharide based edible coating on sapota fruit. *Int. Agrophys.*, **30**: 551-557.

Kester, J.J. and Fennema, O.R. 1986. Edible films and coatings: a review. *Food Technol.*, **40**: 47.

Kluge, R.A., Nachtigal, J.C., Fachinello, J.C., Bilhalva, A.B. and Fisiologiamanae 2002. Jopos-colhita de fruits de Lima temperado; Livrariae editor rural. Companies; Sao Paulo Brazil, pp. 214.

Kore, V.T. and Kabir, J. 2011. Influence of waxing and polyethylene packaging on shelf-life of guava. *Crop Res*., **411(2&3)**: 98-102.

Krochta, J.M., Pavlath, A.E. and Goodman, N. 1990. Edible films from casein-lipid emulsion for lightly processed fruits and vegetables. In: WEL Spiess; H Schubert; editors. Engineering and Food; Preservation processes and related techniques. *Elsevier Applied Sci. Pub. Co*; *London*; **2**: 329–340.

Lee, J.Y., Park, H.J., Lee, C.Y. and Choi, W.Y. 2003. Extending shelf life of minimally processed apples with edible coatings and antibrowning agents. *Leb. Wiss. Technol.*, **36**: 323-329.

Lerdthanangkul, S. and Krochta, J.M. 1996. Edible coating effects on post-harvest quality of green bell peppers. *J. Food Sci.*, **611**: 176-179.

Lim, R., Stathopoulos, C.E. and Golding, J.B. 2011. Effect of edible coatings on some quality characteristics of sweet cherries. *Int. Food Res. J.*, **184**: 1237-1241.

Lima, A.M., Cerqueira, M.A., Souza, B.S., Santos Ed Carlos, M., Teixeira, J.A., Moreira, R.A. and Vicente, A.A. 2010. New edible coatings composed of galactomannans and collagen blends to improve the post-harvest quality of fruits- Influence on fruits gas transfer rate. *J. Food Eng.*, **97**: 101-109.

Lin, D. and Zhao, Y. 2007. Innovation the development and application of edible coating for fresh and minimally processed fruits and vegetables; *Comprehensive* Rev. *Food Sc. & Food Safety*, **6**: 60-75.

Lucera, A., Costa, C., Mastromatteo, M., Conte, A., Del Nobile, M.A. 2010. Influence of different packaging systems on fresh-cut zucchini *(Cucurbita pepo). Innov. Food Sci. Emerg. Technol.*, **11**: 361.

Marpudi, S.L., Abirami, L.S., Pushkala, R. and Srividya, N. 2011. Enhancement of storage life and quality maintenance of papaya fruits using *Aloe vera* based edible antimicrobial coating. *Indian J. Biotechnol*., **10**: 83-89.

Martinez-Romero, D.L., Alburquerque, N., Valverde, J.M., Guillen, F. and Castillo, S. 2006. Post-harvest cherry quality and safety maintenance by *Aloe vera* treatment: A new edible coating. *Post-harvest Biol. Technol.,* **39**: 93-100.

Mehdi, M., Peter, A. and Yasmeen, S. 2011. Effect of a Novel Edible Composite Coating Based on Gum Arabic and Chitosan on Biochemical and Physiological Responses of Banana Fruits during Cold Storage *Journal of Agricultural and Food Chemistry,* **59**(10): 5474-82.

Mehyar, G.F., Al-Ismail, K., Han, J.H. and Chee, G.W. 2012. Characterization of edible coatings consisting of pea starch; whey protein isolate; and carnauba wax and their effects on oil rancidity and sensory properties of walnuts and pine nuts. *J. Food Sci.,* **772**: 52-59.

Milena, P., Francesco, M., Maria, S.P., Luigi, Z., Elvira, N., Giuseppe, C. and Marco, S. 2015. Effect of Chitosan Coating on the Post-harvest Quality and Antioxidant Enzyme System Response of Strawberry Fruit during Cold Storage. *Foods,* **4**: 501-523.

Mota, W.F., Salomao, L.C., Neres, C.R., Mizobutsi, G.P. and Neves, L.L. 2006. Use of carnauba wax and plastic film on post-harvest conservation of the yellow passion fruit. *Revista Brasileira-de-Fruticultura,* **282**: 190-193.

Ochoa, E., Saucedo-Pompa, S., Rojas-Molina, R., Heliodoro, G., Charles-Rodríguez, A.V. and Aguilar, C.N. 2011 Evaluation of a candelilla wax based edible coating to prolong the shelf-life quality and safety of apples. *Amer. J. Agric. Biol. Sci.,* **61**: 92-98.

Oz, A.T. and Ulukanli, Z. 2012. Application of edible starch-based coating including glycerol plus *Oleum nigella* on arils from long-stored whole pomegranate fruits. *J. Food Proc. Pres.,* **361**: 81–95.

Ozden, C. and Bayindirli, Z. 2002. Effects of combinational use of controlled atmosphere; cold storage and edible coating application on shelf life and quality attributes of green peppers. *Eur. Food Res. Technol*., **2144**: 320-326.

Pandey, Kiran 2018. Poor post-harvest storage, transportation facilities to cost farmers dearly. *https://www.downtoearth.org.in/news/agriculture/poor-post-harvest-storage-transportation-facilities-to-cost-farmers-dearly-61047*

Sabir, S.M., Shah, S.A. and Abida-Afzal, 2004. Effect of chemical treatment; wax coating; oil dipping and different wrapping materials on physico-chemical characteristics and storage behaviour of apple Malusdomestica Barkh. *Pak. J. Nutr*., **32**: 122-127.

Sanudo, M.B., Siller-Cepeda, J., Muy-Rangel, D. and Heredia, J.B. 2009. Extending the shelf-life of bananas with 1-methylcyclopropene and a chitosan-based edible coating. *J. Sci. Food Agr.,* **89**: 2343-2349.

Serrano, M., Valverde, J.M., Guillén, F., Castillo, S., Martínez-Romero, D. and Valero, D. 2006. Use of *Aloe vera* gel coating preserves the functional properties of table grapes. *J. Agric. Food Chem*., **5411**: 3882- 3886.

Shon, J. and Choi, Y.H. 2011. Effect of Edible Coatings Containing Soy Protein Isolate (SPI) on the Browning and Moisture Content of Cut Fruit and Vegetables. *J. Appl. Biol. Chem.,* **54**(3): 190-196.

Siracusa, V., Rocculi, P., Romani, S. and Dalla, M. 2008. Biodegradable polymers for food packaging: a review. *Trends Food Sci. Technol*., **19**: 634.

Talens, P., Pérez-Masía, R., Fabra, M.J., Vargas, M. and Chiralt, A. 2012. Application of edible coatings to partially dehydrated pineapple for use in fruitcereal products. *J. Food Eng*., **112**: 86–93.

Tharanathan, R.N. 2003. Biodegradable films and composite coatings: past; present and future. *Trends Food Sci. Technol*., **14**: 71.

Tien, C.L., Vachon, C., Mateescu, M.A. and Lacroix. M. 2001. Milk protein coatings prevent oxidative browning of apples and potatoes. *J. Food Sci.,* **664**: 512.

Tiwari, R. 2014 Post-harvest diseases of fruits and vegetables and their management by biocontrol agents; Department of Botany; University of Lucknow; Lucknow-226007.

Torgul, H. and Arslan, N. 2005. Carboxy-methyl cellulose from sugar beet pulp cellulose as a hydrophilic polymer in coating of apple. *J. Food Sci. Technol*., **422**: 139-144.

Vyas, P.B., Neeta, B., Gol, T.V. and Ramana Rao. 2013. Post-harvest Quality Maintenance of Papaya Fruit Using Polysachharide-Based Edible Coatings. *Int. J. Fruit Sci.,* **14**(1): 81-94.

Xanthopoulos, G., Koronaki, E.D. and Boudouvis, A.G. 2012. Mass transport analysis in perforation-mediated modified atmosphere packaging of strawberries. *J. Food Eng.,* **111**: 326-335.

Xu, S., Xu, D. and Chen, X. 2003. Determining optimum edible films for kiwifruits using an analytical hierarchy process. *Computers & Operations Research,* **30**: 877–886.

Zhou, R., Li, Y., Yan, L. and Xie, J. 2011. Effect of edible coatings on enzymes; cell-membrane integrity; and cell-wall constituents in relation to brittleness and firmness of Huanghua pears Pyruspyrifolia Nakai; cv. Huanghua during storage. *Food Chem.,* **124**: 569-575.