Full Length Article

Effects of Coating Methods and Storage Periods on Some Qualitative Characteristics of Carrot during Ambient Storage

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ABSTRACT

This study was conducted on the effects of Coating Methods (CM) and Storage Periods (SP) on Nantes carrot during ambient storage at temperature of 25°C and 65% relative humidity. Four CM [Carboxy Methyl Cellulose + Cellophane Film (CMC + CF), Carboxy Methyl Cellulose (CMC), Cellophane Film (CF) and No-Coating (NC)] and five SP (0, 4, 8, 11 & 14 days) were investigated for some qualitative characteristics including water content, total soluble solids (TSS), reducing sugars and firmness. The statistical results of the study indicated that CM and SP significantly ($P \leq 0.01$) affected all traits. Interaction of CM × SP for all traits was also significant. The statistical results of the study indicated that CMC + CF for water content and reducing sugars and CF for firmness were the best CM. In addition, water content, reducing sugars and firmness decreased by increasing the SP, whereas TSS increased by an increase in SP.

Key Words: Carrot; Ambient storage; Carboxy methyl cellulose; Storage period; Total soluble solids; Reducing sugars; Firmness

INTRODUCTION

Carrot (*Daucus carota* L.) belongs to the family Umbelliferae. The carrot is believed to have originated in Asia and now under cultivation in many countries. The carrot is an important vegetable, because of its large yield per unit area throughout the world and its increasing importance as human food. It is orange-yellow in color, which adds attractiveness to foods on a plate and makes it rich in carotene, a precursor of vitamin A. It contains appreciable quantities of nutrients such as protein, carbohydrate, fiber, vitamin A, potassium, sodium, thiamine and riboflavin and is also high in sugar. Its use increases resistance against the blood and eye diseases. It is eaten raw as well as cooked in curries and is used for pickles and sweetmeats (Ahmad *et al.*, 1994; Ahmad *et al.*, 2005; Hassan *et al.*, 2005).

Methods that are being used to preserve whole fruits and vegetables during storage and marketing are generally based on refrigeration with or without control of composition of the atmosphere (Smith & Stow, 1984; Smith *et al.*, 1987). However, temperature, atmosphere, relative humidity and sanitation must be regulated to maintain quality of them (Watada *et al.*, 1996; Mostofi & Toivonen, 2006). In this direction, several methods that have been used are refrigeration, controlled atmosphere packaging, modified atmosphere packaging and chemical preservatives (Ahmad & Khan, 1987; Baldwin *et al.*, 1996; Zhang &

Quantick, 1997). The most prevalent method is rapid cooling at a low temperature with high relative humidity (El Ghaouth *et al.*, 1991). However, low temperature storage is not economically feasible in most developing countries (Smith *et al.*, 1987; Li & Yu, 2000).

Fungicides control postharvest decay of whole fruits, but they leave residues that are potential risks to humans and the environment (Li & Yu, 2000). In addition, many consumers are suspicious of chemicals in their foods, especially in fruits and vegetables (Baldwin *et al.*, 1996). Sulfites were effective chemical preservative as they were both inhibitors of enzymatic browning and antimicrobial. But their use has been banned due to adverse reaction in consumers (Kim *et al.*, 1993; Baldwin *et al.*, 1996). Moreover, chemical preservatives affect the flavor of fruits and vegetables (Rocha *et al.*, 1998).

Plastic films are also effective in reducing desiccation (moisture loss), but are subject to microbial growth and disposal problems (Lerdthanangkul & Krochta, 1996; Zhang & Quantick, 1997). It takes many years of research to develop a material that would coat fruit so that an internal modified atmosphere would develop (Park *et al.*, 1994a & b). Studies have shown that ripening can be retarded, color changes can be delayed, water loss and decay can be reduced and appearance can be improved by using a simple and environmentally friendly technology, edible coating (Park *et al.*, 1994a & b; Baldwin, 2001). The concept of edible films as protective films has been used since the

1800s (Guilbert *et al.*, 1996). The first edible coating used was wax in China (Park, 1999). Extensive research in this area has paved the way for different effective edible films and coatings.

The use of edible films and coatings is extended for a wide range of food products including fresh fruits and vegetables. The reasons for their use are: they extend product shelf life (Park *et al.*, 1994a & b), control oxidation and respiration reactions (McHugh & Krochta, 1994a & b), add to texture and sensory characteristics and are environmentally friendly (Guilbert *et al.*, 1996). Krochta (2001) indicated that the present commercial edible coatings are solvent based (ethanol) and the food industry should replace these solvent-based coatings with water-based coatings to ensure worker and environmental safety.

Coatings are applied and formed directly on the surface of the food product, whereas films are structures, which are applied after being formed separately. Because they may be consumed the material used for the preparation of edible films and coatings should be approved by Food and Drug Administration (FDA) and must conform to the regulations that apply to the food product concerned (Guilbert *et al.*, 1996). The purpose of edible films or coatings is to inhibit migration of moisture, oxygen, carbon dioxide, or any other solute materials, serve as a carrier for food additives like antioxidants or antimicrobials and reduce the decay without affecting quality of the food. Specific requirements for edible films and coatings are: 1. The coating should be water-resistant so as to remain intact and to cover all parts of a product adequately when applied: 2. It should not deplete oxygen or build up excessive carbon dioxide. A minimum of 1-3% oxygen is required around a commodity to avoid a shift from aerobic to anaerobic respiration: 3. It should reduce water vapor permeability: 4. It should improve appearance, maintain structural integrity, improve mechanical handling properties, carry active agents (antioxidants, etc.) and retain volatile flavor compounds (Arvanitoyannis & Gorris, 1999).

Edible coatings are thin layers of edible material applied to the product surface in addition to or as a replacement for natural protective waxy coatings and provide a barrier to moisture, oxygen and solute movement for the food (Smith *et al.*, 1987; Nisperos-Carriedo *et al.*, 1992; Guilbert *et al.*, 1996; Lerdthanangkul & Krochta, 1996; Avena-Bustillos *et al.*, 1997; McHugh & Senesi, 2000). They are applied directly on the food surface by dipping, spraying or brushing to create a modified atmosphere (Guilbert *et al.*, 1996; Krochta & Mulder-Johnston, 1997; McHugh & Senesi, 2000). An ideal coating is defined as one that can extend storage life of fresh fruit without causing anaerobiosis and reduces decay without affecting the quality of the fruit (El Ghaouth *et al.*, 1992b). Previously, edible coatings have been used to reduce water loss, but recent developments of formulated edible coatings with a wider range of permeability characteristics has extended the potential for fresh produce application (Avena-

Bustillos *et al.*, 1994). Also, the effect of coatings on fruits and vegetables depends greatly on temperature, alkalinity, thickness and type of coating and the variety of and condition of fruits (Park *et al.*, 1994a & b). The functional characteristics required for the coating depend on the product matrix (low to high moisture content) and deterioration process to which the product is subject (Guilbert *et al.*, 1996).

Edible coatings may be composed of polysaccharides, proteins, lipids or a blend of these compounds (Mahmoud & Savello, 1992; Park *et al.*, 1994a & b; Guilbert *et al.*, 1996; Li & Barth, 1998; Arvanitoyannis & Gorris, 1999). Their presence and abundance determine the barrier properties of material with regard to water vapor, oxygen, carbon dioxide and lipid transfer in food systems (Guilbert *et al.*, 1996). However, none of the three constituents can provide the needed protection by themselves and so are usually used in a combination for best results (McHugh & Krochta, 1994a & b; Guilbert *et al.*, 1996).

Some of the polysaccharides that have been used in coating formulations are starch and pectin (Baldwin, 2001), cellulose (Li & Barth, 1998; Baldwin, 2001; Tien *et al.*, 2000), chitosan (El Ghaouth *et al.*, 1991; El Ghaouth *et al.*, 1992a; Cheah *et al.*, 1997; Zhang & Quantick, 1998; Li & Yu, 2000; Baldwin, 2001; Jiang & Li, 2001) and alginate (Tien *et al.*, 2000; Baldwin, 2001). These films are excellent oxygen, aroma and oil barriers and provide strength and structural integrity; but are not effective moisture barriers due to their hydrophilic nature (Kester & Fennema, 1986; Krochta, 2001). The oxygen barrier properties are due to their tightly packed, ordered hydrogen bonded network structure and low solubility (Banker, 1966). These coatings may retard ripening and increase shelf life of coated produce, without creating severe anaerobic conditions (Baldwin *et al.*, 1995; Arvanitoyannis & Gorris, 1999).

In this paper, the effect Coating Methods (CM) and Storage Periods (SP) on some qualitative characteristics of Nantes carrot including water content, total soluble solids (TSS), reducing sugars and firmness during ambient storage at temperature of 25°C and 65% relative humidity is reported.

MATERIALS AND METHODS

Plant materials. Carrots (*Daucus carota* L., cv. Nantes) were purchased from a local market in Karaj, Iran. They were visually inspected for freedom of defects and blemishes. Carrots were then washed with tap water and treated for the prevention of development of decay by dipping for 20 min at 20°C in 0.5 g L^{-1} aqueous solution of iprodione and then air dried for approximately 1 h.

CMC application. Carrots were placed in 30 L plastic boxes and soaked for 5 min at 20°C in 20 g L^{-1} aqueous solution of CMC. They were then removed from the plastic boxes and then air dried for approximately 1 h.

Water content. The water content of carrots was determined using the Eq. (1):

Water content (%) = 100 × (M_1-M_2)/M_1 (1).

Where:

M_1 = Mass of sample before drying, g.

M_2 = Mass of sample after drying, g.

Total soluble solids (TSS). The total soluble solids of carrots (TSS) was measured using an ATC-1E hand-held refractometer (ATAGO, Japan) at temperature of 20°C.

Reducing sugars. The reducing sugars of carrots were determined using Fehling method. This method can be used as a basis for the analysis of reducing sugars. Fehling's solution contains Cu^{2+} ions that can be reduced by some sugars to Cu^+ ions. As the Fehling's solution is added the blue Cu^{2+} ions will be reduced to Cu^+ ions. These will precipitate out of solution as red Cu^+ ions. The resulting solution will be colorless. A titration can be carried out to determine an equivalent amount of the sugar to the Fehling's solution. The end point would be when the blue color has just disappeared. This reaction can be used for the quantitative analysis of reducing sugars (Mendham *et al.*, 2000).

Firmness. The firmness of carrots was analyzed using a Hounsfield texture analyzer (Hounsfield Corp., UK). The test used was a shear or cut test on the 50 g carrot pieces closely placed into a 6 × 6 × 6 cm test box with 8 chisel knife blades. The variations in carrots size and geometry were minimized by testing the pieces of same thickness from the carrots. The test mode used for the texture analysis was "Force in Compression". A 5000 N load cell, test speed of 100 mm min^{-1} and post-test speed 600 mm min^{-1} were used. The "Trigger Type" was set to "Button" and distance to be traveled was set to 68 mm. Based on the average firmness of carrots in 0-days (3200 N); the range of the cutting force was set to 2000-3400 N and the maximum cutting force measured during each test was considered as stiffness.

Statistical analysis. The experiment had factorial structure with four CM [Carboxy Methyl Cellulose + Cellophane Film (CMC + CF), Carboxy Methyl Cellulose (CMC), Cellophane Film (CF) and No-Coating (NC)] and five SP (0, 4, 8, 11 & 14 days) at temperature of 25°C and 65% relative humidity. The experiment had a complete random design for each factor combination with three replications. The effects of the factors on each qualitative characteristic were determined by analysis of variance using SPSS 12.0 (Version, 2003). Also, Duncan's Multiple Range Test (DMRT) at 1% probability ($P \leq 0.01$) was performed to compare the means of different treatments.

RESULTS AND DISCUSSION

Effect on water content. CM and SP significantly affected water content (Table I). The highest water content of 84.95% was observed in the first CM (CMC + CF) and lowest (81.75%) in the fourth CM (NC) and CM affected water content in the order of CMC + CF > CF > CMC > NC (Table II). Moreover, the highest water content of 87.80% was observed in 0-days and lowest (79.69%) in 14 days SP and water content decreased with increased SP (Table II). Furthermore, interaction of CM × SP showed significant effect on water content (Table I). The study of CM and SP combinations on water content showed that in each CM water content had the highest value in 0-days and lowest value in 14 days SP. The maximum mean value for water content was observed in 0-days of each CM and minimum mean value for water content was observed in 14 days SP and the fourth CM (NC). Also in each SP CM affected water content in the same order as mentioned before (Table III). These results are in agreement with those of Mahmoud and Savello (1992) and Avena-Bustillos *et al.* (1997) who concluded that coatings and/or films significantly conserved water content. These results are also in line with the results reported by Smith and Stow (1984), El Ghaouth *et al.* (1992b) and Baldwin *et al.* (1996) that water content significantly decreased with increased SP.

Effect on total soluble solids (TSS). The effect of CM and SP on TSS was found significant (Table I). The highest TSS of 10.5% was observed in the fourth CM (NC) and lowest (9.03%) in the first CM (CMC + CF) and CM affected TSS in the order of NC > CMC > CF > CMC + CF (Table II). Moreover, the highest TSS of 11.0% was observed in 14 days SP and lowest (8.63%) in 0 days and TSS increased with increased SP (Table II). Furthermore, interaction of CM × SP showed significant effect on TSS (Table I). Mean comparison of CM × SP combinations on TSS revealed that in each CM TSS had the highest value in 14 days SP and lowest value in 0 days. The maximum mean value for TSS was observed in 14 days SP and the fourth CM (NC) and minimum mean value for TSS was observed in 0 days of each CM. Also in each SP CM affected TSS in the same order as mentioned before (Table III). These results are in agreement with those of Smith and Stow (1984) who concluded that coatings and/or films significantly affected TSS. These results are also in line with the results reported by Park *et al.* (1994a & b) and Hussain *et al.* (2005) that TSS significantly increased by increasing SP.

Effect on reducing sugars. The effect of CM and SP on reducing sugars was also found significant (Table I). The highest reducing sugars of 7.99% was observed in the first CM (CMC + CF) and lowest (7.44%) in the fourth CM (NC) and CM affected reducing sugars in the order of CMC + CF > CMC > CF > NC (Table II). Moreover, the highest reducing sugars of 8.26% was observed in 0 days and lowest (6.97%) in 14 days SP and reducing sugars decreased with increased SP (Table II). Furthermore, interaction of CM × SP showed significant effect on reducing sugars (Table I). The study of CM and SP combinations on reducing sugars showed that in each CM reducing sugars had the highest value in 0 days and lowest value in 14 days SP. The maximum mean value for reducing sugars was observed in 0 days of each CM and minimum mean value for reducing sugars was observed in 14 days SP and the fourth CM (NC). Also in each SP CM

Table I. Analysis of variance for several carrot quality characteristics

Source of variation	Df	Mean square			
		Water content	TSS	Reducing sugars	Firmness
CM	3	26.46 **	5.393 **	1.105 **	129544 **
SP	4	125.0 **	10.64 **	3.217 **	355513 **
CM × SP	12	3.098 **	0.700 **	0.201 **	16557.1 **
Error	38	0.406	0.001	0.006	268.582
C.V. (%)	---	0.76	0.36	1.00	0.55

** = Significant at 0.01 probability level

Table II. Means comparison for different carrot quality characteristics for different studied treatments using DMRT at 1% probability

Treatment		Water content (%)	TSS (%)	Reducing sugars (%)	Firmness (N)
CM	CMC + CF	84.95 a	9.03 d	7.99 a	3022 b
	CMC	83.62 b	10.0 b	7.88 b	2944 c
	CF	83.81 b	9.81 c	7.50 c	3076 a
	NC	81.75 c	10.5 a	7.44 c	2863 d
LSD₁%		0.631	0.031	0.077	16.23
SP	0 - days	87.80 a	8.63 e	8.26 a	3200 a
	4 - days	85.49 b	9.17 d	8.07 b	3086 b
	8 - days	83.34 c	9.92 c	7.80 c	2963 c
	11 - days	81.34 d	10.5 b	7.41 d	2864 d
	14 - days	79.69 e	11.0 a	6.97 e	2767 e
LSD₁%		0.705	0.035	0.086	18.14

Means in the same column with different letters differ significantly at 0.01 probability level according to DMRT

affected reducing sugars in the same order as mentioned before (Table III). These results are in agreement with those of Ahmad and Khan (1987), El Ghaouth *et al.* (1991) and Li and Yu (2000) and McHugh and Senesi (2000) who concluded that coatings and/or films significantly affected reducing sugars. These results are also in line with the results reported by Suojala (2000) and Forney *et al.* (2007) that reducing sugars significantly decreased with increased SP.

Effect on firmness. CM and SP significantly affected firmness (Table I). The highest firmness of 3076 N was observed in the third CM (CF) and lowest (2862%) in the fourth CM (NC) and CM affected firmness in the order of CF > CMC + CF > CMC > NC (Table II). Moreover, the highest firmness of 3200 N was observed in 0 days and lowest (2767 N) in 14 days SP and firmness decreased with increased SP (Table II). Furthermore, interaction of CM × SP showed significant effect on firmness (Table I). Mean comparison of CM × SP combinations on firmness revealed that in each CM firmness had the highest value in 0 days and lowest value in 14 days SP. The maximum mean value for firmness was observed in 0 days of each CM and minimum mean value for firmness content was observed in 14 days SP and the fourth CM (NC). Also in each SP CM affected firmness in the same order as mentioned before (Table III). These results are in line with the results reported by Lerdthanangkul and Krochta (1996) who concluded that coatings and/or films significantly affected firmness. These results are also in line with the results reported by Mostofi

Table III. Means comparison for different carrot quality characteristics of Coating Method (CM) and Storage Period (SP) combinations using DMRT at 1% probability

CM	×	SP	Water content (%)	TSS (%)	Reducing sugars (%)	Firmness (N)
		0 - days	87.80 a	8.63 n	8.26 a	3200 a
		4 - days	86.25 b	8.83 m	8.17 ab	3108 bc
CMC+CF		8 - days	84.82 bcd	9.10 l	8.03 bcd	3015 e
		11 - days	83.49 de	9.17 l	7.86 d	2934 gh
		14 - days	82.41 ef	9.40 j	7.64 e	2852 i
		0 - days	87.80 a	8.63 n	8.26 a	3200 a
		4 - days	85.51 bc	9.27 k	8.13 abc	3063 e
CMC		8 - days	83.44 de	10.2 h	7.95 cd	2912 h
		11 - days	81.50 fg	10.8 e	7.62 e	2830 i
		14 - days	79.85 hi	11.2 c	7.42 f	2714 j
		0 - days	87.80 a	8.63 n	8.26 a	3200 a
		4 - days	85.64 bc	9.13 l	8.01 bcd	3135 b
CF		8 - days	83.58 de	9.80 i	7.63 e	3072 cd
		11 - days	81.93 f	10.5 g	7.13 g	3004 ef
		14 - days	80.12 gh	11.0 d	6.48 h	2968 fg
		0 - days	87.80 a	8.63 n	8.26 a	3200 a
		4 - days	84.58 cd	9.47 j	7.98 cd	3037 de
NC		8 - days	81.52 fg	10.6 f	7.58 ef	2854 i
		11 - days	78.46 i	11.4 b	7.05 g	2688 j
		14 - days	76.38 j	12.2 a	6.35 h	2535 k
LSD₁%			1.411	0.070	0.172	36.28

Means in the same column with different letters differ significantly at 0.01 probability level according to DMRT

and Toivonen (2006) that firmness significantly decreased by increasing SP.

CONCLUSION

Coating Methods (CM) and Storage Periods (SP) significantly ($P \leq 0.01$) affected water content total soluble solids (TSS), reducing sugars and firmness of Nantes carrot during ambient storage at temperature of 25°C and 65% relative humidity. Results of the study indicated that Carboxy Methyl Cellulous + Cellophane Film (CMC + CF) for water content and reducing sugars and Cellophane Film (CF) for firmness were the best CM. In addition, water content, reducing sugars and firmness decreased by increasing the SP, whereas TSS increased by an increase in SP.

REFERENCES

Ahmad, M. and I. Khan, 1987. Effects of waxing and cellophane lining on chemical quality indices of citrus fruits. *Plant Food Human Nutr.*, 37: 47–57

Ahmad, B., M.A. Chaudhry and S. Hassan, 1994. *Cost of Producing Major Crops in Punjab*. Department of farm Management, University of Agriculture, Faisalabad, Pakistan

Ahmad, B., S. Hassan and K. Bakhsh, 2005. Factors affecting yield and profitability of carrot in two districts of Punjab. *Int. J. Agric. Biol.*, 7: 794–798

Arvanitoyannis, I. and L.G.M. Gorris, 1999. Edible and biodegradable polymeric materials for food packaging or coating. *In: Processing Foods: Quality Optimization and Process Assessment*, pp: 357–371. CRC Press, Boca Raton, FL

Avena-Bustillos, R.J., J.M. Krochta and M.E. Saltveit, 1997. Water vapor resistance of red delicious apples and celery sticks coated with edible caseinate-acetylated monoglyceride films. *J. Food Sci.*, 62: 351–354

Avena-Bustillos, R.J., L.A. Cisneros-Zevallos, J.M. Krochta and M.E. Saltveit, 1994. Application of casein-lipid edible film emulsions to reduce white blush on minimally processed carrots. *Postharvest Biol. Technol.*, 4: 319–329

Baldwin, E.A., 2001. *New Coating Formulations for the Conservation of Tropical Fruits*, http://technofruits2001.cirad.fr 10/08/2002

Baldwin, E.A., M.O. Nisperos-Carriedo and R.A. Baker, 1995. Use of edible coatings to preserve quality of lightly (and slightly) processed products. *Crit. Rev. Food Sci. Nutr.*, 35: 509–552

Baldwin, E.A., M.O. Nisperos-Carriedo, X. Chen and R.D. Hagenmaier, 1996. Improving storage life of cut apple and potato with edible coating. *Postharvest Biol. Technol.*, 9: 151–163

Banker, G.S., 1966. Film coating theory and practice. *J. Pharmaceut. Sci.*, 55: 81–89

Cheah, L.H., B.B.C. Page and R. Shepherd, 1997. Chitosan coating for inhibition of sclerotinia rot of carrots. *New Zealand J. Crop Hort. Sci.*, 25: 89–92

El Ghaouth, A., J. Arul, R. Ponnampalam and M. Boulet, 1991. Chitosan coating effect on storability and quality of fresh strawberries. *J. Food Sci.*, 56: 1618–1620

El Ghaouth, A., J. Arul, J. Grenier and A. Asselin, 1992a. Antifungal activity of chitosan on two postharvest pathogens of strawberry fruits. *Phytopathol.*, 82: 398–402

El Ghaouth, A., J. Arul, R. Ponnampalam and M. Boulet, 1992b. Chitosan coating to extend the storage life of tomatoes. *Hort. Sci.*, 27: 1016–1018

Forney, C.F., J. Song, P.D. Hildebrand, L. Fan and K.B. McRae, 2007. Interactive effect of ozone and 1-methylcyclopropene on decay resistance and quality of stored carrots. *Postharvest Biol. Technol.*, 45: 341–348

Guilbert, S., N. Gontard and L.G.M. Gorris, 1996. Prolongation of the shelf-life of perishable food products using biodegradable films and coatings. *Lebensmittel-Wissenschaft Technol.*, 29: 10–17

Hassan, I., K. Bakhsh, M.H. Salik, M. Khalil and N. Ahmad, 2005. Determination of factors contributing towards the yield of carrot in Faisalabad (Pakistan). *Int. J. Agric. Biol.*, 7: 323–324

Hussain, I., S.N. Gilani, M.R. Khan, M.T. Khan and I. Shakir, 2005. Varietal suitability and storage stability of mango squash. *Int. J. Agric. Biol.*, 7: 1038–1039

Jiang, Y. and Y. Li, 2001. Effects of chitosan on postharvest life and quality of longan fruit. *Food Chem.*, 73: 139–143

Kester, J.J. and O.R. Fennema, 1986. Edible films and coatings. A review. *Food Technol.*, 40: 47–59

Kim, D.M., N.L. Smith and C.Y. Lee, 1993. Quality of minimally processed apple slices from selected cultivars. *J. Food Sci.*, 58: 1115–1117

Krochta, J.M., 2001. *FAQ About Edible Films and Coatings*, http://www.dairybiz.com/feature.htm 05/07/2002

Krochta, J.M. and C.D. Mulder-Johnston, 1997. Edible and biodegradable polymer films: Challenges and Opportunities. *Food Technol.*, 51: 61–74

Lerdthanangkul, S. and J.M. Krochta, 1996. Edible coating effects on post harvest quality of green bell peppers. *J. Food Sci.*, 61: 176–179

Li, H. and T. Yu, 2000. Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. *J. Sci. Food Agric.*, 81: 269–274

Li, P. and M.M. Barth, 1998. Impact of edible coatings on nutritional and physiological changes in lightly processed carrots. *Postharvest Biol. Technol.*, 14: 51–60

Mahmoud, R. and P.A. Savello, 1992. Mechanical properties of and water vapor transferability through whey protein films. *J. Dairy Sci.*, 75: 942–946

Mendham, J., R.C. Denney, J.D. Barnes and M. Thomas, 2000. *Vogel's Textbook of Quantitative Chemical Analysis*. Pearson Education Ltd., England

McHugh, T.H. and E. Senesi, 2000. Apple wraps: A novel method to improve the quality and extend the shelf life of fresh-cut apples. *J. Food Sci.*, 65: 480–485

McHugh, T.H. and J.M. Krochta, 1994a. Milk protein based edible films and coatings. *Food Technol.*, 48: 97–103

McHugh, T.H. and J.M. Krochta, 1994b. Sorbitol vs glycerol plasticized whey protein edible films: Integrated oxygen permeability and tensile property evaluation. *J. Agric. Food Chem.*, 42: 41–45

Mostofi, Y. and P.M.A. Toivonen, 2006. Effects of storage conditions and 1-methylcyclopropene on some qualitative characteristics of tomato fruits. *Int. J. Agric. Biol.*, 8: 93–96

Nisperos-Carriedo, M.O., E.A. Baldwin and P.E. Shaw, 1992. Development of an edible coating for extending postharvest life of selected fruits and vegetables. In: *Proc. Annul. Meeting Florida State Hort. Soc.*, 104: 122–125

Park, H.J., 1999 Development of advanced edible coatings for fruits. *Trends Food Sci. Technol.*, 10: 254–260

Park, H.J., M.S. Chinnan and R.L. Shewfelt, 1994a. Edible coating effects on storage life and quality of tomatoes. *J. Food Sci.*, 59: 568–570

Park, H.J., M.S. Chinnan and R.L. Shewfelt, 1994b. Edible corn-zein film coatings to extend storage life of tomatoes. *J. Food Proc. Preservest*, 18: 317–331

Rocha, A.M.C.N., C.M. Brochado and A.M.M.B. Morais, 1998. Influence of chemical treatment on quality of cut apple (cv. Jonagored). *J. Food Qual.*, 21: 13–28

Smith, S.M. and J.R. Stow, 1984. The potential of a sucrose ester coating material for improving the storage and shelf-life qualities of Cox's Orange Pippin apples. *Annl. Appl. Biol.*, 104: 383–391

Smith, S.M., J. Geeson and J.R. Stow, 1987. Production of modified atmospheres in deciduous fruits by the use of films ad coatings. *Hort. Sci.*, 22: 772–776

Suojala, T., 2000. Variation in sugar content and composition of carrot storage roots at harvest and during storage. *Sci. Hort.*, 85: 1–19

Tien, C.L., M. Letendre, P. Ispas-Szabo, M.A. Mateescu, G.D. Patterson, H.L. Yu and M. Lacroix, 2000. Development of biodegradable films from whey proteins by cross-linking and entrapment in cellulose. *J. Agric. Food Chem.*, 48: 5566–5575

Watada, A.E., N.P. Ko and D.A. Minott, 1996. Factors affecting quality of fresh-cut horticultural products. *Postharvest Biol. Technol.*, 9: 115–125

Zhang, D. and P.C. Quantick, 1997. Effects of chitosan coating on enzymatic browning and decay during postharvest storage of litchi (*Litchi chinensis Sonn.*) fruit. *Postharvest Biol. Technol.*, 12: 195–202

Zhang, D. and P.C. Quantick, 1998. Antifungal effects of chitosan coating on fresh strawberries and raspberries during storage. *J. Hort. Sci. Biotechnol.*, 73: 763–767