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INTERACTIVE EFFECTS OF COATING METHOD AND STORAGE PERIOD ON QUALITY OF CARROT (CV. NANTES) DURING AMBIENT STORAGE

Majid Rashidi[1] and Mahdi Hosseini Bahri[2]
[1]Department of Agricultural Machinery, Faculty of Agriculture, Islamic Azad University, Takestan Branch, Iran
[2]Varamin Agricultural Engineering Research Department, Agricultural Engineering Research Institute, Iran
E-Mail: majidrashidi81@yahoo.com , m.rashidi@aeri.ir

ABSTRACT

This study was conducted on the interactive 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 and 14-days) were investigated for some qualitative characteristics including water content, total soluble solids (TSS), reducing sugar and firmness. A factorial experiment design was laid out in completely randomized design with 3 replications for each one of factors and Duncan's multiple range tests were performed to compare the means of different treatments. 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 sugar, and CF for firmness were the best CM. In addition, water content, reducing sugar and firmness decreased by increasing the SP, whereas TSS increased by an increase in SP.

Keywords: carrot, ambient storage, carboxy methyl cellulose, cellophane film, storage period.

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 and 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 and Toivonen, 2006). In this direction, several methods that have been used are refrigeration, controlled atmosphere packaging, modified atmosphere packaging and chemical preservatives (Ahmad and Khan, 1987; Baldwin *et al.*, 1996; Zhang and 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 and Yu, 2000).

Fungicides control postharvest decay of whole fruits, but they leave residues that are potential risks to humans and the environment (Li and 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 and Krochta, 1996; Zhang and Quantick, 1997). Many years of research are conducted 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 and 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

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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 and 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 and Krochta, 1996; Avena-Bustillos *et al.*, 1997; McHugh and 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 and Mulder-Johnston, 1997; McHugh and 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 and Savello, 1992; Park *et al.*, 1994a, b; Guilbert *et al.*, 1996; Li and Barth, 1998; Arvanitoyannis and 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 and 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 and Barth, 1998; Baldwin, 2001; Tien *et al.*, 2000), chitosan (El Ghaouth *et al.*, 1991; El Ghaouth *et al.*, 1992a; Cheah *et al.*, 1997; Zhang and Quantick, 1997; Zhang and Quantick, 1998; Li and Yu, 2000; Baldwin, 2001; Jiang and 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 and 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 and Gorris, 1999).

In this paper, the interactive effects of Coating Method (CM) and Storage Period (SP) on some qualitative characteristics of Nantes carrot including water content, total soluble solids (TSS), reducing sugar 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-liter 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):

$$\text{Water content (\%)} = 100\times (M_1 - M_2)/M_1 \qquad (1)$$

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) were measured using an ATC-1E hand-held refractometer (ATAGO, Japan) at temperature of 20°C.

Reducing sugar

The reducing sugar of carrots was determined using Fehling method. This method can be used as a basis for the analysis of reducing sugars. Fehling's solution

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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 and 14-days) at temperature of 25°C and 65% relative humidity. The experiment had a complete random design for each factor combination with 3 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 tests (DMRT) at 1% probability were performed to compare the means of different treatments.

RESULTS AND DISCUSSION

Effect on water content

CM and SP significantly ($P \leq 0.01$) affected water content (Table-1). 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-2). 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-2). Furthermore, interaction of CM × SP showed significant effect ($P \leq 0.01$) on water content (Table-1). 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-3). 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 ($P \leq 0.01$) (Table-1). 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-2). 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-2). Furthermore, interaction of CM × SP showed significant effect ($P \leq 0.01$) on TSS (Table-1). 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-3). 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 sugar

The effect of CM and SP on reducing sugar was also found significant ($P \leq 0.01$) (Table-1). The highest reducing sugar of 7.99% was observed in the first CM (CMC + CF) and lowest (7.44%) in the fourth CM (NC), and CM affected reducing sugar in the order of CMC + CF > CMC > CF > NC (Table-2). Moreover, the highest reducing sugar of 8.26% was observed in 0-days and lowest (6.97%) in 14-days SP and reducing sugar decreased with increased SP (Table-2). Furthermore, interaction of CM × SP showed significant effect ($P \leq 0.01$) on reducing sugar (Table-1). The study of CM and SP combinations on reducing sugar showed that in each CM reducing sugar had the highest value in 0-days and lowest value in 14-days SP. The maximum mean value for reducing sugar was observed in 0-days of each CM, and minimum mean value for reducing sugar was observed in 14-days SP and the fourth CM (NC). Also, in each SP CM affected reducing sugar in the same order as mentioned before (Table-3). 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 sugar. These results are also in line with the results reported by Suojala (2000) and Forney *et al.* (2007)

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that reducing sugar significantly decreased with increased SP.

Effect on firmness

CM and SP significantly (P ≤ 0.01) affected firmness (Table-1). 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-2). 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-2). Furthermore, interaction of CM × SP showed significant effect (P ≤ 0.01) on firmness (Table-1). 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-3). 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 and Toivonen (2006) that firmness significantly decreased by increasing SP.

Table-1. Analysis of variance for several carrot quality characteristics.

Source of variation	Df	Mean square			
		Water content	TSS	Reducing sugar	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-2. Means comparison for different carrot quality characteristics for different studied treatments using DMRT at 1% probability.

Treatment		Water content (%)	TSS (%)	Reducing sugar (%)	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
$LSD_{1\%}$		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
$LSD_{1\%}$		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

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Table-3. 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 sugar** (%)	**Firmness** (N)
CMC + CF	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
	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
CMC	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
	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
CF	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
	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
NC	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
	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
$LSD_{1\%}$		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

CONCLUSIONS

Coating Methods (CM) and Storage Periods (SP) significantly ($P \leq 0.01$) affected water content, total soluble solids (TSS), reducing sugar 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 sugar, and Cellophane Film (CF) for firmness were the best CM. In addition, water content, reducing sugar and firmness decreased by increasing the SP, whereas TSS increased by an increase in SP.

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REFERENCES

Ahmad B. Chaudhry M.A. and Hassan S. 1994. Cost of producing major crops in Punjab, Department of farm Management, University of Agriculture, and Faisalabad.

Ahmad B. Hassan S. and Bakhsh K. 2005. Factors affecting yield and profitability of carrot in two districts of Punjab. International Journal of Agriculture and Biology, 7: 794-798.

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Ahmad M. and Khan I. 1987. Effects of waxing and cellophane lining on chemical quality indices of citrus fruits. Plant foods for Human Nutrition. 37: 47-57.

Arvanitoyannis I. and Gorris L.G.M. 1999. Edible and biodegradable polymeric materials for food packaging or coating in processing foods: Quality optimization and process assessment. CRC Press, Boca Raton, FL. pp: 357-371.

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

Avena-Bustillos R.J. Cisneros-Zevallos L.A. Krochta J.M. and Saltveit M.E. 1994. Application of casein-lipid edible film emulsions to reduce white blush on minimally processed carrots. Postharvest Biology and Technology. 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. Nisperos-Carriedo M.O. and Baker R.A. 1995. Use of edible coatings to preserve quality of lightly (and slightly) processed products. Critical Reviews in Food Science and Nutrition. 35: 509-552.

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

Banker G.S. 1966. Film coating theory and practice. Journal of Pharmaceutical Science. 55: 81-89.

Cheah L.H. Page B.B.C. and Shepherd R. 1997. Chitosan coating for inhibition of sclerotinia rots of carrots. New Zealand Journal of Crop and Horticultural Science. 25: 89-92.

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

El Ghaouth A. Arul J. Ponnampalam R. and Boulet M. 1991. Chitosan coating effect on storability and quality of fresh strawberries. Journal of Food Science. 56: 1618-1620.

El Ghaouth A. Arul J. Ponnampalam R. and Boulet M. 1992b. Chitosan coating to extend the storage life of tomatoes. Horticulture Science. 27: 1016-1018.

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

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

Hassan I. Bakhsh K. Salik M.H. Khalil M. and Ahmad N. 2005. Determination of factors contributing towards the yield of carrot in Faisalabad (Pakistan). International Journal of Agriculture and Biology. 7: 323-324.

Hussain I. Gilani S.N. Khan M.R. Khan M.T. and Shakir I. 2005. Varietal suitability and storage stability of mango squash. International Journal of Agriculture and Biology, 7: 1038-1039.

Jiang Y. and Li Y. 2001. Effects of chitosan on postharvest life and quality of longan fruit. Food Chemistry. 73: 139-143.

Kester J.J. and Fennema O.R. 1986. Edible films and coatings. A review. Food Technology. 40: 47-59.

Kim D.M. Smith N.L. and Lee C.Y. 1993. Quality of minimally processed apple slices from selected cultivars. Journal of Food Science. 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 Mulder-Johnston C.D. 1997. Edible and biodegradable polymer films: Challenges and Opportunities. Food Technology. 51: 61-74.

Lerdthanangkul S. and Krochta J.M. 1996. Edible coating effects on post harvest quality of green bell peppers. Journal of Food Science. 61: 176-179.

Li H. and Yu T. 2000. Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. Journal of the Science of Food and Agriculture. 81: 269-274.

Li P. and Barth M.M. 1998. Impact of edible coatings on nutritional and physiological changes in lightly processed carrots. Postharvest Biology and Technology. 14: 51-60.

Mahmoud R. and Savello P.A. 1992. Mechanical properties of and water vapor transferability through whey protein films. Journal of Dairy Science. 75: 942-946.

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

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

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

McHugh T.H. and Krochta J.M. 1994b. Sorbitol vs glycerol plasticized whey protein edible films: Integrated oxygen permeability and tensile property evaluation. Journal of Agricultural and Food Chemistry, 42: 41-45.

Mostofi Y. and Toivonen P.M.A. 2006. Effects of storage conditions and 1-methylcyclopropene on some qualitative characteristics of tomato fruits. International Journal of Agriculture and Biology. 8: 93-96.

Nisperos-Carriedo M.O. Baldwin E.A. and Shaw P.E. 1992. Development of an edible coating for extending postharvest life of selected fruits and vegetables. Proceedings at the annual meeting of Florida State Horticultural Society. 104: 122-125.

Park H.J. 1999. Development of advanced edible coatings for fruits. Trends in Food Science and Technology. 10: 254-260.

Park H.J. Chinnan M.S. and Shewfelt R.L. 1994a. Edible coating effects on storage life and quality of tomatoes. Journal of Food Science. 59: 568-570.

Park H.J. Chinnan M.S. and Shewfelt R.L. 1994b. Edible corn-zein film coatings to extend storage life of tomatoes. Journal of Food Processing and Preservation. 18: 317-331.

Rocha A.M.C.N. Brochado C.M. and Morais A.M.M.B. 1998. Influence of chemical treatment on quality of cut apple (cv. Jonagored). Journal of Food Quality. 21: 13-28.

Smith S.M. and Stow J.R. 1984. The potential of a sucrose ester coating material for improving the storage and shelf-life qualities of Cox’s Orange Pippin apples. Annals of Applied Biology. 104: 383-391.

Smith S.M. Geeson J. and Stow J.R. 1987. Production of modified atmospheres in deciduous fruits by the use of films ad coatings. Horticultural Science. 22: 772-776.

Suojala T. 2000. Variation in sugar content and composition of carrot storage roots at harvest and during storage. Scientia Horticulturae. 85: 1-19.

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

Watada A.E. Ko N.P. and Minott D.A. 1996. Factors affecting quality of fresh-cut horticultural products. Postharvest Biology and Technology. 9: 115-125.

Zhang D. and Quantick P.C. 1997. Effects of chitosan coating on enzymatic browning and decay during postharvest storage of litchi (Litchi chinensis Sonn.) fruit. Postharvest Biology and Technology. 12: 195-202.

Zhang D. and Quantick P.C. 1998. Antifungal effects of chitosan coating on fresh strawberries and raspberries during storage. Journal of Horticultural Science and Biotechnology. 73: 763-767.