Original Article Asian J Agri Biol, 2013, 1(3):133-140.

EFFECT OF EDIBLE COATINGS OF CARBOXY METHYL CELLULOSE AND CORN STARCH ON CUCUMBER STORED AT AMBIENT TEMPERATURE

Adetunji Charles Oluwaseun[1]*, Arowora Kayode A[1], Fawole Oluyemisi Bolajoko[2], Adetunji Juliana Bunmi[3] and Olagbaju AR[1]

[1]*Nigerian Stored Product Research Institute, Km 3 Asa Dam Road, P.M.B. 1489, Ilorin, Kwara State, Nigeria.*
[2]*University of Ilorin, Department of Agronomy, P.M.B. 1515, Ilorin, Kwara State, Nigeria.*
[3]*University of Ilorin, Department of Biochemistry, P.M.B. 1515, Ilorin, Kwara State, Nigeria.*

ABSTRACT

Edible coating has been used for preserving the quality and safety of fresh fruit and vegetables. The ability of polysaccharide-based (carboxy methyl cellulose and corn starch) coatings to extend the shelf life and quality of cucumber fruit during storage at ambient temperature of 25-28^{o}C and relative humidity of 83-95% was investigated . The results indicated that coated cucumber showed a significant delay in weight loss, firmness, pH, total soluble solids, ascorbic acid and total microbial counts compared to uncoated ones. Sensory evaluation results showed that coatings maintained the visual quality of the cucumber during the storage time. The results suggested using carboxy methyl cellulose and corn starch can extend the shelf life of cucumber during storage in ECS for 7 weeks.

Keywords: Carboxy methyl cellulose, Corn starch, Cucumber fruit, Edible coatings

INTRODUCTION

Cucumber (*Cucumis sativa* L.) is one of the most important and popular vegetable crops all over the world including Nigeria. The crop is mainly cultivated during the summer season in open fields. It could be grown in two growing seasons, autumn and spring under plastic house conditions. (Abd EL-Kereem, 1998).

Edible films and coatings are environment friendly alternative method to extend the postharvest life of fresh and minimally processed fruits and vegetables (Baldwin, 1994; Olivas *et al.,* 2008; Pérez-Gago *et al.,* 2005; Vargas *et al.,* 2008). They form a semipermeable barrier to gases and water vapor and thereby reduce respiration and weight loss. In addition, edible films and coatings may help maintaining firmness and provide gloss to coated fruit.

Edible films and coatings also improve mechanical handling properties; carry additives, avoiding loss of volatile compounds and production of volatile aroma (Olivas and Barbosa-Ca´ novas, 2005).

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). 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, 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).

Carboxymethyl cellulose (CMC) is a linear, long-chain, water-soluble, anionic polysaccharide. Purified CMC is a white to cream-colored, tasteless, odorless, free-flowing powder (Keller, 1986; Hattori *et al.*, 2004).

**Corresponding author* e-mail: charliguitar@yahoo.com

From the literature reviews, corn starch appears to be an interesting alternative for edible films due to it is abundance, cheap price, being biodegradable as well as edible (Biliaderis *et al*., 1999; Wing *et al*., 1988; Bertuzzi *et al.,* 2007).

MATERIALS AND METHODS

Source of fruits and Coating materials

Cucumber fruits were purchased from Ipata market in Ilorin on the day after harvest and were immediately placed in ambient storage (27±3^{o}C). Uniform sized, defect-free fruits were selected. Corn starch (CS) and Carboxymethyl cellulose (CMC) were bought from lab trade company Ilorin. Glycerol (99.5%) was purchased from Sigma Chemical Co.

Preparation of edible coatings

Carboxymethyl Cellulose coating (3%) was prepared by dissolving 6.0 g of CMC powder (Hangzhou Hongbo Chemical Co. Ltd, China) in 200 ml of water ethyl alcohol mixture (3:1) at 80^{o}C and stirred for 10 min using magnetic stirrer. Ethyl alcohol was added in order to reduce drying time and obtain a transparent and shiny coating. 2% volume of propylene glycol was also added in the formulation as plasticizer.

Corn Starch films were prepared as follows. Aqueous suspension of 3g CS/100g with plasticizers was preheated at 100^{o}C for 30 min in boiling water-bath, gelatinized at 160±5^{o}C in an oil bath for 30 min, cooled to 80^{o}C, cast on the round polypropylene (PP) plate (300mm ID, 305mm OD and 10mm depth), and then dried at 50^{o}C for 24 h in an oven. Glycerol was added to 100g of corn starch as plasticizers. The dried powder from CS is then mixed with the glycerol.

Treatments

T_o (control):- T_0 was selected as the control (untreated cucumber)

T_1 Cucumber was coated with CMC.

T_2 Cucumber was coated with CS.

The treated and untreated was packed in small plastic basket and each basket contain 20 cucumber fruits. The basket was stored at ambient temperature (25^{o}C, 95-98% RH); physicochemical analysis was carried out from week 1-7 after coating.

Weight loss: To evaluate weight loss, separate samples in 3 replicates of each treatments were used. The same samples were evaluated for weight loss each time at weekly intervals until the end of experiment. Weight loss was determined by the following formula:

Weight loss (%) = [(A−B)/A] x 100

where A indicates the fruit weight at the time of harvest and B indicates the fruit weight after storage intervals (A.O.A.C., 1994)

Firmness:- Firmness was measured as the maximum penetration force (N) reached during tissue breakage, and determined with a 5 mm diameter flat probe. The penetration depth was 5 mm and the cross-head speed was 5 mm s^{-1} using a TA-XT2 Texture Analyzer (Stable Micro Systems, Godalming, UK), MA. Cucumber were sliced into halves and each half was measured in the central zone.

pH:- After firmness analysis, cucumber was cut into small pieces and homogenized in a grinder, and 10 g of ground cucumber was suspended in 100 ml of distilled water and then filtered. The pH of the samples was assessed using a pH meter (pH-526; WTW Measurement Systems, Wissenschaftlich, Technische Werksta¨tten GmbH, Wellhelm, Germany).

Total soluble solids (TSS):- Total soluble solids (TSS) were measured by the method described by Dong *et al*., (2001). Individual cucumber fruit from each of the treatment was grinded in an electric juice extractor for freshly prepared juice. Soluble solids content was measured using T/C hand refractometer in Brix% (Model 10430 porx-reading 0-30 range Bausch and Lomb Co. Califonia, USA.

Ascorbic acid:- Ascorbic acid content was measured using 2, 5-6 dicholorophenol indophenols' method described by A.O.A.C (1994).

Microbial analysis

Thirty grams of cucumber fruit pulps was removed aseptically from each treatment. The sample was then homogenized in peptone saline solution (8.5 g/l NaCl + 1 g/l peptone for 1 min in a stomacher (S400, Shanghai Scientific Instrument Co., Ltd., Shanghai, China). After making serial dilutions in peptone water, the samples were plated on different media as follows: (1) plate count agar (PCA), for isolating total aerobic psychrotrophic micro-organisms was incubated at 12^{o}C for 72 h and mesophilic micro-organisms was incubated at 30^{o}C for 72 h; (2) Sabouraud media (Oxoid CM41) for isolating yeasts and moulds was incubated at 25^{o}C for 120 h. Colonies were counted and the results expressed as $CFUg^{-1}$ of cucumber. Analyses were carried out periodically in randomly sampled from the baskets. Two replicate counts were performed for each tray (ICMSF, 1983).

Statistics

Data was analyzed by using the appropriate statistical analysis of the variance. Mean ± S.E were found. The significance level used was 0.05. For all statistical analysis SPSS software (version 12.0, SPSS Inc., US) was used.

RESULTS AND DISCUSSION

The mean ± SE value for the firmness coatings from CS and CMC on cucumber were 2807.14 ± 399.27 and 2688.57 ± 427.66 while the mean ± SE value for the uncoated was 2274.29 ± 508.59.

Lerdthanangkul and Krochta (1996) also made similar observations and concluded that coatings and/or films significantly affected firmness of fruits in storage. The softening process in orange was reported to be dependent on the increase in polygalacturonase, ß-galactosidase and pectinmethylesterase activities (Batisse *et al*., 1996; Rem´on *et al*., 2003), being responsible for fruit quality loss. In addition, CS and CMC probably had some effects on the reduction of cell wall degrading-enzymes responsible for cucumber softening. These results show beneficial effects of the CS and CMC coatings on increasing the cucumber shelf life, since it has been postulated that fruit softening and texture changes during orange storage determine fruit storage ability and shelf life, as well as reduce incidence of decay and lessened susceptibility to mechanical damage (Batisse *et al*., 1996; Vidrih *et al*., 1998).

The mean ± SE value for the TSS coatings from CS and CMC on cucumber were 9.97 ± 0.50 and 9.40 ± 0.29 while the mean ± SE value for the uncoated was 7.59 ± 0.29. These results are similar with those of Smith and Stow (1984) in which they concluded that coatings and/or films significantly affected TSS. Soluble solids content of coated and uncoated cucumber stored under ambient condition decreased at the end of the storage period. The loss of soluble solids during the storage period is as natural as sugars which are the primary constituent of the soluble solids content of a product, consumed by respiration and used for the metabolic activities of the fruits (Özden and Bayindirli, 2002).

The mean ± SE values for the Percentage weight loss of coatings from CS and CMC on cucumber were 70.56 ± 3.59 and 66.73 ± 3.06 while the mean ± SE value for the uncoated was 63.25 ± 9.56. These results are in confirmation with those of Mahmoud and Savello (1992) and (Avena-Bustillos *et al.,* 1997). They concluded that coatings and/or films significantly conserved water content. Post-harvest weight changes in fruits and vegetables are usually due to the loss of water through transpiration. This loss of water can lead to wilting and shriveling; both reduce a commodity’s marketability. Edible films and coatings can also offer a possibility to extend the shelf life of fresh-cut produce by providing a semi-permeable barrier to gases and water vapor and therefore, they can reduce respiration, enzymatic browning and water loss (Guilbert, 1986; Baldwin and Nisperos-CarriedoBaker, 1995).

Ascorbic acid is lost due to the activities of phenol oxidase and ascorbic acid oxidase enzymes during storage (Salunkhe *et al*., 1991). while studying green bean, spinach and broccoli, postulated that the lower the oxygen content of the storage atmosphere, the smaller is the loss of ascorbic acid. The claim was that the oxidation of Vitamin C was mainly regulated by ascorbic acid oxidase and other oxidases, most of which had a low affinity for oxygen. Ascorbic acid content decreased for cherries stored at both ambient temperature and cold temperature. CS and CMC coatings were effective in reducing the ascorbic acid loss for the storage conditions (Fig. 5). At the ambient temperature, the ascorbic acid contents of CS and CMC coated cucumber were significantly different from the control cucumber. The reduction of ascorbic acid loss in coated cucumber was due to the low oxygen permeability of CS and CMC coating which lowered the activity of the enzymes and prevented oxidation of ascorbic acid.

The pH of cucumber gradually increased during storage. The mean ± SE value for the pH of coatings from CS and CMC on cucumber were 3.65 ± 0.11 and 3.47 ± 0.06 while the mean ± SE value for the uncoated was 3.46 ± 0.44, from this ,there were no significant differences between treated and control fruits, although, the CS and CMC showed higher pH at the end of 7weeks of storage (Fig. 3). This was probably because the semi-permeable from CS and CMC formed on the surface of the fruit might have modified the internal atmosphere, i.e., the endogenous CO_2

and O_2 concentration of the fruit, thus retarding ripening.

Fig. 6 shows the total mesophilic aerobic counts during storage of coated and uncoated cucumber. The initial mesophilic microbial load in control samples from CS and CMC were 2.3 and 3.4 log CFU/g in the first week while that of the control was 4.3 log CFU/g. This result is consistent with that reported by Olarte *et al*. (2009) for broccoli. The mean ± SE value for the mesophilic aerobic counts of coatings from CS and CMC on cucumber were 4.24 ± 0.60 and 5.31 ± 0.72 log CFU/g while the mean ± SE value for the uncoated was 6.39 ± 0.79 log CFU/g. Results revealed that the application of CS and CMC coating significantly reduced ($p < 0.05$) total microbial counts in comparison to the uncoated samples. The results of mesophilic aerobic counts showed the effectiveness of CS and CMC as antimicrobial agent. The antimicrobial action of CS and CMC has been reported by other authors in minimally processed garlic (Geraldine *et al*., 2008) and fresh-cut cantaloupe and pineapple (Sangsuwan *et al*., 2008). The control of decay in coated cucumber could be attributed to the modified atmosphere originated by the edible coating from CS and CMC (Dutta *et al*., 2009). According to current Spanish regulations (BOE, 2001), which establish a maximum count level of 7 log CFU/g of aerobic mesophilic microorganisms, the application of CS and CMC coatings meant a shelf life extension of cucumber. The coated cucumber with CS and CMC were able to hinder the microorganisms to lower microbial load of 6.8 and 8.4 log CFU/g respectively while the uncoated cucumber had a higher microbial load of 10.2 log CFU/g.

The predominant microflora which influences the shelf life of fruits and vegetables are psychrotrophic bacteria (Garcia-Gimeno & Zurera-Cosano, 1997; Hotchkiss & Banco, 1992). The initial physchrotropics microbial load in control samples from CS and CMC were 2.9 and 2.6 log CFU/g in the first week while that of the control was 4.1 log CFU/g. Changes in the total aerobic Psychrotrophic count, in cucumber stored for seven weeks at an average temperature of 27 ± 2°C and relative humidity 55-60% are shown in Fig 7. The mean ± SE value for the aerobic psychrotrophic counts of coatings from CS and CMC on cucumber were 3.73 ± 0.24 and 4.51 ± 0.55 log CFU/g while the mean ± SE value for the uncoated was 7.41 ± 1.35 log CFU/g. During the period of storage coating from CS and CMC which significantly hindered the increase in total aerobic psychrotrophic count compared with the control samples ($p<0.05$) (Fig. 7). The coated cucumber with CS and CMC were able to hindered the microorganisms to lower microbial load of 4.7 and 6.735 log CFU/g respectively while the uncoated cucumber had a higher microbial load of 14.635 log CFU/g because of the absence of any inhibiting substance to the psychrotrophic microorganisms around the surface area of cucumber fruit.

Changes in the total number of yeasts and moulds in cucumber stored for seven weeks at 25°C and relative humidity 95-98% are shown in Fig 8. The initial yeasts and moulds load in control samples from CS and CMC was 2.5 and 3.5 log CFU/g in the first week while that of the control was 4.2 log CFU/g. The mean ± SE value for yeast and moulds counts of coatings from CS and CMC on cucumber were 4.23 ± 0.57 and 5.03 ± 0.87 log CFU/g while the mean ± SE value for the uncoated was 6.86 ± 0.95 log CFU/g. During the period of storage coating hindered the increase in aerobic yeasts and moulds count compared with the control samples (Fig. 8). The coated cucumber with CS and CMC were able to hindered the microorganisms to lower microbial load of 6.7 and 7.3 log CFU/g respectively while the uncoated cucumber had a higher microbial load of 11.3 log CFU/g. These results are in agreement with those found by other authors who used other type of edible coatings. Lee *et al*. (2003) reported very similar results for minimally processed apples with various types of carbohydrate polymers and whey protein concentrate, using ascorbic acid, citric acid and oxalic acid as anti-browning agents. Howard and Dewi (1995) used an edible cellulose-based coating, on minipeeled carrots and investigated microbial quality during storage at 21ºC. As stated by Olivas and Barbosa-Ca´novas (2005), coatings create a modified atmosphere that may change the growth rate of spoilage and pathogenic microorganisms.

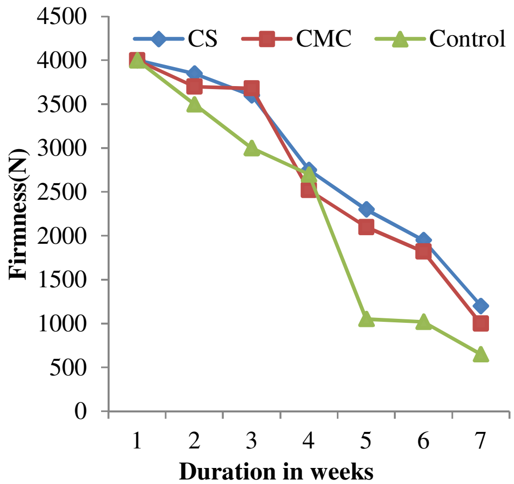

Fig1: Effect of CS and CMC on firmness of cucumber fruit stored at ambient temp of 25°C

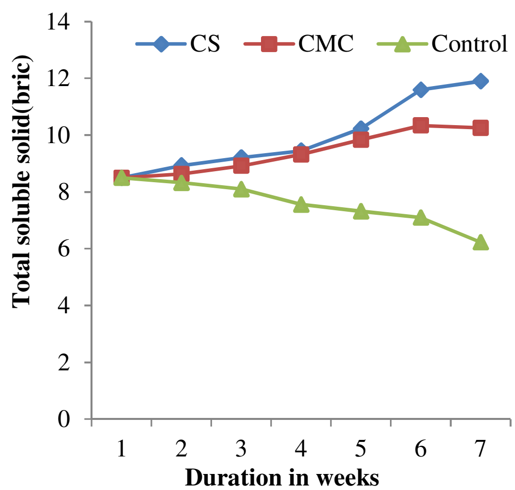

Fig2: Effect of CS and CMC on TSS of cucumber fruit stored at ambient temp of 25°C

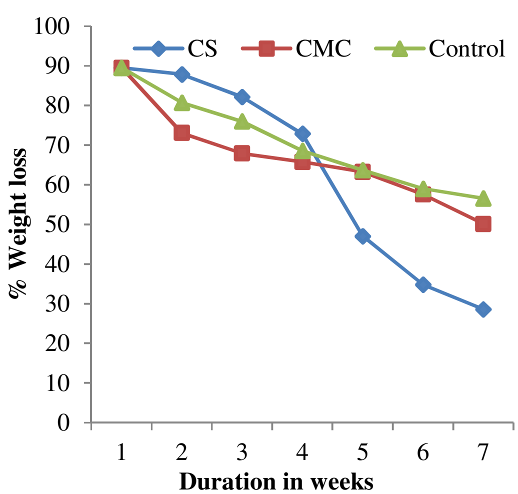

Fig3: Effect of CS and CMC on % Weight loss of cucumber fruit stored at ambient temp of 25°C

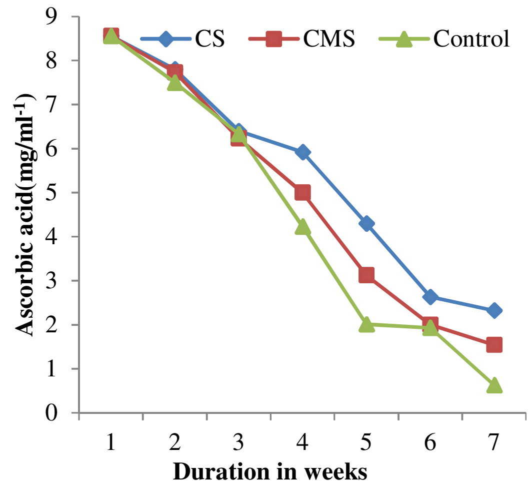

Fig 4: Effect of CS and CMC on Ascorbic acid of cucumber fruit stored at ambient temp of 25°C

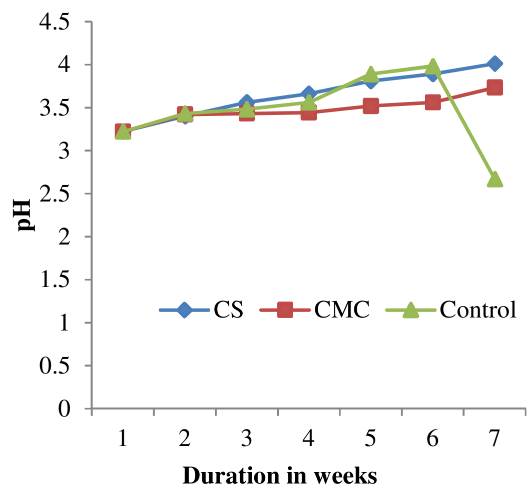

Fig5: Effect of CS and CMC on pH of cucumber fruit stored at ambient temp of 25°C

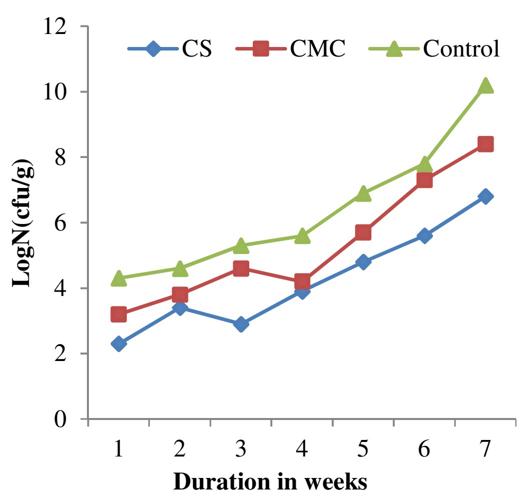

Fig 6: Effect of CS and CMC on mesophilic organisms of cucumber fruit

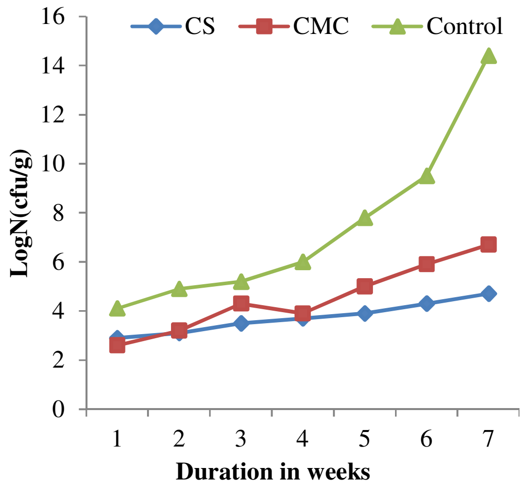

Fig7: Effect of CS and CMC on mesophilic organisms of cucumber fruit

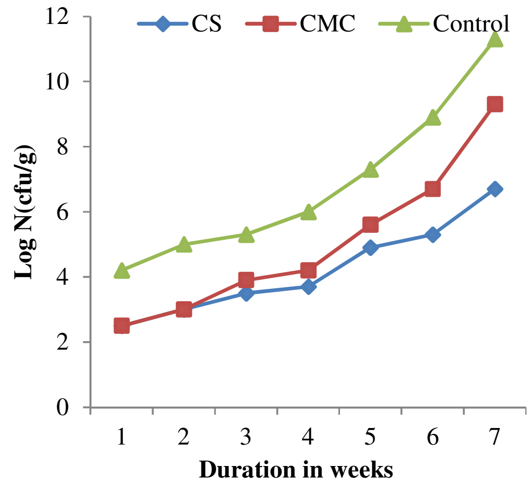

Fig8: Effect of CS and CMC on yeast and mould organisms of cucumber fruit

CONCLUSIONS

The edible coatings, Corn starch and carboxymethyl cellulose, seemed to have a beneficial impact on quality parameters of cucumber by slowing their weight loss, pH, firmness, total soluble solid, microbial growth and ascorbic acid retention.

However significant differences were observed among these coatings: cornstarch was superior during storage maintaining cucumber fruit in higher quality levels relative to CMC coating. In conclusion, the quality maintenance and the shelf life extension of cucumber reveal that corn starch coating can be considered for commercial application during storage and marketing of cucumber fruit.

REFERENCES

Abd EL-Kereem, F, 1998. Induction of resistance to some diseases of cucumber plants grown under greenhouse conditions. Ph.D. Thesis, Faculty of Agriculture, Ain Shams University, Egypt.

AOAC, 1994. Official Methods of Analysis. Association of Official Analytical Chemists. 1111 North 19th Street, Suite 20, 16th Edi. Arlington, Virginia, USA. 22209.

Arvanitoyannis I. and Gorris LGM. 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 RJ, Krochta JM, and Saltveit ME, 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.

Baldwin, EA, Nisperos-Carriedo, MO and Baker RA, 1995. Use of edible coatings to preserve quality of lightly (and slightly) processed products. Critical Review Food Science Nutrition. 35, 509–524.

Baldwin EA,1994a . Edible coatings for fresh fruits and vegetables: past, present, and future. In J. M. Krochta, EA. Baldwin, & MO. Nisperos-Carriedo (Eds.), Edible coatings and films to improve food quality (pp. 25e64). Lancaster, PA, USA: Technomic Publishing Co. Inc.

Baldwin EA, 2001b . New coating formulations for the conservation of tropical fruits. http://technofruits2001.cirad.fr 10/08/2002.

Batisse, C, Buret, M, Coulomb, PJ, 1996. Biochemical differences in cell wall of cherry fruit between soft and crisp fruit. J. Agric. Food Chem. 44, 453–457.

Bertuzzi, MA, Castro Vidaurre, EF , Armada, M, Gottifredi, JC, 2007. Water vapor permeability of edible starch based films. Journal of Food Engineering, 80, 972-978.

Biliaderis, CG, Lazaridou, A and Arvanitoyannis, I, 1999. Glass transition and physical properties of polyol-plasticised pullulan–starch blends at low moisture Carbohydrate Polymers. 40, 29-47.

Boletín Oficial del Estado (BOE), 2001. Real Decreto 3484/2000, of 29 December, establishing norms of hygiene for the production, distribution and commercialization of prepared food. BOE no. 11 of 12 January 2001, Ministerio de la Presidencia, Madrid, p. 1440.

Cheah LH, 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.

Dutta PK, Tripathi, S, Mehrotra, GK, Dutta, J, 2009. Perspectives for chitosan based antimicrobial films in food applications. Food Chem. 114, 1173–1182.

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, 1991b. Chitosan coating effect on storability and quality of fresh strawberries. Journal of Food Science. 56: 1618-1620.

Geraldine RM, Ferreira Soares, NF, Botrel, DA, Gonc¸ alves, LA, 2008. Characterization and effect of edible coatings on minimally processed garlic quality. Carbohyd. Polym. 72, 403–409.

Guilbert S, 1986. Technology and application of edible protective films. In Mathlouthi, M. (Ed.), Food packaging and preservation, p. 371–394. London, UK: Elsevier Applied Science.

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

Hattori K, Abe E, Yoshida T. and Cuculo JA, 2004. New solvents for cellulose II ethylenediamine/thiocyanate salt system. Polymer Journal. 36(2), 123–130.

Hotchkiss J, & Banco M, 1992. Influence of packaging technologies on the growth of microorganisms in produce. Journal of Food Protection. 55, 815–820.

Howard LR and Dewi T, 1995. Sensory, microbiological and chemical quality of mini-peeled carrots as affected by edible coating treatment. Journal of Food Science. 60(1), 142–144.

ICMSF, 1983. Métodos recomendados para el análisis microbiológico en alimentos. In: ICMSF, Microorganismos de los Alimentos I. Técnicas de Análisis, Microbiológicos, Acribia, Zaragoza, pp. 105–280.

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

Keller JD, 1986. In: M. Gliksman, Editor, Sodium carboxymethylcellulose (CMC), Food Hydrocolloids*,* 3, CRC Press, Boca Raton, Florida, pp. 45–104.

Kester JJ and Fennema OR, 1986. Edible films and coatings. A review. Food Technology. 40: 47-59.

Krochta JM, 2001. FAQ about edible films and coatings. Http://www.daIrybIz.com/feature.htm 05/07/2002.

Lee JY, Park H J, Lee C Y, & Choi WY, 2003. Extending shelflife of minimally processed apples with edible coatings and antibrowning agents. Lebensmittel-Wissenschaft und-Technologie, 36, 323–329.

Lerdthanangkul S and Krochta JM, 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 MM, 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 PA, 1992. Mechanical properties of and water vapor transferability through whey protein films. Journal of Dairy Science. 75: 942-946.

McHugh T and Krochta JM, 1994a. Permeability properties of edible films. In: Edible Coatings and Films to Improve Food Quality, edited by Krochta JM. Baldwin EA, Nisperos-Carriedo MO. pp. 139-187.Technomic Publishing Co., Lancaster, *PA.*

McHugh T and Krochta JM, 1994b. Sorbitol- vs glycerol-plasticized whey protein edible films: integrated oxygen permeability and tensile property evaluation. Journal of Agriculture and Food Chemistry. 42:841-845.

Olarte C, Sanz S, Echávarri JF, Ayala, F, 2009 . Effect of plastic permeability and exposure to light during storage on the quality of minimally processed broccoli and cauliflower, LWT – Food Sci. Technol. 42, 402–411.

Olivas G I, Dávila-Aviña, JE, Salas-Salazar, NA., & Molina, FJ, 2008. Use of edible coatings to preserve the quality of fruits and vegetables during storage. Stewart Postharvest Review. 3(6), 1-10.

Olivas GI, and Barbosa-Ca´ novas, GV, 2005. Edible coatings for fresh-cut fruits. Critical Reviews in Food Science and Nutrition. 45, 657–670.

Özden, C & Bayindirli L, 2002. Effects of combinational use of controlled atmosphere, cold storage and edible coating applications on shelf life and quality attributes of apples. European Food Research Technology. 214, 320–326.

Park HJ, Chinnan MS and Shewfelt RL, 1994. Edible coating effects on storage life and quality of tomatoes. Journal of Food Science. 59: 568-570.

Pérez-Gago MB, Serra M, Alonso M, Mateos M, & del Río, MA, 2005. Effect of whey protein- and hydroxypropyl methylcellulose-based edible composite coatings on color change of fresh-cut apples. Postharvest Biology and Technology. 36(1), 77-85.

Rem´on, S, Venturini, ME, L´opez-Buesa P, Oria R, 2003. Burlat cherry quality after long range transport, I optimisation of packaging conditions. Inno. Food Sci. Emerg. Technol. 4, 425–434.

Salunkhe DK, Boun HR, Rddy NR, 1991. Storage Processing and Nutritional Quality of Fruits and Vegetables, vol. 1. Fresh Fruits and Vegetables. Boston: CRC Press Inc.

Sangsuwan J, Rattanapanone N, Rachtanapun P, 2008. Effect of chitosan/methyl cellulose films on microbial and quality characteristics of fresh-cut cantaloupe and pineapple. Postharvest Biol. Technol. 49, 403–410.

Smith SM. and Stow JR, 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.

Tien CL, Letendre M, Ispas-Szabo P, Mateescu MA, Patterson GD, Yu HL, 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.

Vargas M, Pastor C, Chiralt A, McClements DJ, & González-Martínez C, 2008. Recent Advances in edible coatings for fresh and minimally processed fruits, Critical Reviews in Food Science & Nutrition, 48, 496-511.Vidrih, R., Zavrtanik, M., Hribar, J, 1998 . Effect of low O_2, high CO_2 or added acetaldehyde and ethanol on postharvest physiology of cherries. Acta Hort. 2, 693–695.

Weichmann J, 1985. Postharvest Physiology of Vegetables, New York: Marcel Dekker Wing, R. E., Maiti, S. and Doane, W. M. (1988) Amylose content of starch controls the release of encapsulated bioactive agents, Journal of Controlled Release. 7, 33-37.

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