

EFFECTS OF CHITOSAN AND SOME IMMERSION SOLUTIONS ON THE QUALITY AND SHELF LIFE OF SLICED MANGO

Abd El-Al, G. A.; Amal A. Gab-Allah, R. A. Taha and Noha E. Morsy
Food Technology Dept., Fac. of Agric., Suez Canal Univ., Ismailia,
Egypt.

ABSTRACT

Manually sliced mango was treated with aqueous solutions of 1% chitosan; 2g/l citric acid, 200ppm vitamin E (VE), 200ppm ascorbic acid and 200ppm vitamin E + 1% chitosan. Mango slices were placed in plastic trays and over-wrapped with low density polyethylene (LDPE) film and then stored at 4°C (± 1). Physical and chemical changes (TSS, firmness and weight loss), microbial quality (Total bacterial count, yeasts and moulds, psychrotrophs and *Pseudomonas* Spp. bacteria) and sensory qualities (appearance, taste, aroma, color and texture) were evaluated. All coated mango slices exhibited smaller loss in weight than uncoated control slices, and the slices coated with chitosan groups showed the lowest weight losses. Generally, all coating treatments significantly enhanced the firmness of mango slices ($P < 0.05$) regardless coating type. It was obvious from the results that the formulation of VE +chitosan had the highest firmness during all time of storage. Chitosan containing VE formulation maintained the firmness more than chitosan or VE alone. On the other hand, adding of VE to chitosan formulation did not enhance the efficiency of chitosan for preventing the increasing cell load. The results revealed that applying chitosan coating effectively improved the quality attributes and extended the shelf life of mango slices.

INTRODUCTION

Mango (*Mangifera indica* L.) is a climacteric fruit with a high commercial value on the international fruit market (Baldwin *et al.*, 1999). Restaurants and consumers like sliced mango for convenience of serving and consumption. However, minimally processed foods are typically stored between 4 and 8°C and sliced mango fruit are very perishable because they lack protective pericarp (Tovar *et al.*, 2001). Additionally, the pulp is very vulnerable to dehydration, color breaking to dark and disease (Baldwin *et al.*, 1999). External and internal qualities are crucial to consumer acceptability, and an important marketing consideration. Hence, alternative methods are needed for preserving the quality attributes of the flesh of sliced mango during handling, distribution and retail sale. Minimally processed fruits (MPF) and vegetables contain living tissue that has undergone minor changes from its fresh state. The cutting or splicing operation forms a lesion in the tissue (Tovar *et al.*, 2001). MPF have a shorter shelf life than whole fruits and vegetables, partially because of the physiological changes that occur in wounded viable tissue (Baldwin *et al.*, 1995). The post-harvest physiology and maintenance of the quality of freshly cut fruit have been studied for kiwifruit, banana, peach, apple, melon (Kader and Gorny, 1998), strawberries, (Palmer and Kader, 1997), halved papaya (Paull and Chen, 1997), pear

cubes (Pittia *et al.*, 1999) and mango slices immersed in CaCl_2 , citric acid, H_2O_2 and sodium benzoate (Tovar *et al.*, 2001). However, consumers around the world demand high-quality food, without chemical preservatives so an increased effort has been made to discover new natural preservatives and antimicrobials.

The main objective of this study was to study the effect of some dip treatment of aqueous solutions of 1% chitosan; 2g/l citric acid, 200ppm vitamin E (VE), 200ppm ascorbic acid and 200ppm vitamin E + 1% chitosan on the quality and shelf life of mango slices during chill storage assessed by chemical, microbiological and sensory parameters.

MATERIALS AND METHODS

Mango (*Mangifera indica* L.) used in the experimental work of this study was 'Zepda' variety in pre-ripening stage bought from a local farm, Ismailia Governorate-Egypt. Fruits were transferred immediately after harvesting to the laboratory in a cool box. The fruits of superior quality in terms of uniformity of size, color, and shape as well as absence of any physical damages and fungal infections were selected for the experiment. Selected fruits were peeled manually with a very sharp knife, and then cut into slices with dimensions of approximately 5×4×1 cm. Slices were divided to six groups, one group were kept without treatment to serve as a control. Slices of the other groups were treated with only one coat by dipping slices of each group in one of the following solutions for 2 min: (Citric acid solution 2g/l, Chitosan solution 1%, Vitamin E solution 200ppm, Ascorbic acid solution 200ppm, Vitamin E 200ppm + Chitosan 1% solution). For preparing 1% chitosan-coating solutions, 10g chitosan originated from crab shells (Sigma-Aldrich, Oakville, Canada) was added to 1.0 l deionized water containing 10g of glacial acetic acid. The mixture was stirred at 40 °C for 1h using a magnetic stirrer/hotplate. Glycerol was added to the solution as a plasticizer at a level of 1.0 ml/g chitosan and stirred for additional 10 min. The resultant chitosan coating solution was filtered to remove any undissolved particles.

Slices were picked up carefully from dipping solutions and then allowed to dry in air for 30 min at room temperature (20±1°C). Slices were placed in plastic trays and over-wrapped with low density polyethylene (LDPE) film (cling film). All trays of mango slices were immediately stored in a refrigerator at 4-5 °C to be examined at 0, 3, 6, 9, 12, and 20 days. Physical and chemical analysis (Weight loss, total soluble solids, and firmness) and microbial analysis (Total bacterial counts, yeast and molds, psychrotrophs, *Pseudomonas* spp.) were carried out for each group at each storage time to evaluate the overall quality of the mango slices.

2.1. Physical and chemical analysis

The soluble solids content in each slice was determined according to AOAC (1995) in the juice of each sample using abbe refractometer (Hergeselt 753087, Germany). The pH and titratable acidity of the sample filtrate were assessed using a pH meter (Jenway 3305, UK) and titration to

pH 8.1 using 0.1mol/l NaOH. Titratable acidity was expressed as g citric acid per 100 g fresh weight (Hernández-Munóz *et al.*, 2006).

The firmness of each mango slice was determined by Effigi penetrometer (model FT 011, Alfonsine, Italy) with a plunger diameter of 11.1 mm for depth of 7.9 mm on opposite sides of each slice and the results were expressed as kg/cm².

To determine weight loss, slices were weighed at the beginning of the experiment just after coating and then air-dried, and thereafter each analysis during the storage period. Weight loss was expressed as percentage loss of the initial total weight.

2.2. Color measurement

According to Mendoza and Aguilera (2004) and Yam and Papadakis (2004), the color of the sample was expressed as an average value of red (R), green (G) and blue (B) for all pixels in the image of the sample. In addition, to facilitate differentiation between samples, the RGB components were also converted to L*a*b* color space. A digital color image with a resolution of 600×800 pixels was acquired for tested sample using an image acquisition unit. The unit consists of (1) digital CCD camera Powershot (Canon Co., USA), (2) illumination unit consisting of four 50W halogen lamps adjusted at angle of 45° to illuminate the camera's field of view, (3) white nylon tent to equally disperse and distribute the light over sample (4) a base covered with black velvet for holding tested sample to act as background, and (5) a computer to record images acquired by the camera. A program written in Matlab7.1 (Release 14, The MathWorks Inc., MA, USA) was developed for controlling the unit and for processing images to extract color parameters from each sample.

The acquired color images were processed to extract the R, G and B color components. Also, the normalized color components (r, g and b) were calculated using the following formulas:

$$r = R/(R+G+B) \quad (1)$$

$$g = G/(R+G+B) \quad (2)$$

$$b = B/(R+G+B) \quad (3)$$

Finally, all color images were also transformed into CIE L*a*b* color space format. The L*a*b* color space is an international standard for color measurement developed by the Commission Internationale d'Eclairage (CIE) in 1976. The L*a*b* values are often used in food research studies (Yam and Papadakis, 2004). Where the 'L*' stands for color lightness (varies from 255 for perfect white to zero for black), the 'a*' defines the color degree between red and green (zero indicates green while 255 indicates red), and the 'b*' indicates the color degree between yellow and blue (zero indicates blue and 255 indicates yellow).

2.3. Microbiological analysis

For microbiological analyses, about 10 g of mango from slices of each treatment were homogenized in a stomacher (Universal laboratory AID type MPW, Japan) for 2 min with 90 ml of sterile peptone water. Serial dilutions (1:10) of each homogenized sample were made in the same diluent and surface spread in duplicate. Total aerobic bacteria and psychrotrophs were determined using Plate Count Agar; plate was incubated at 30°C for 48

h and 7°C for 10 days, respectively. In addition, plate count agar containing 100µg/ml chloramphenicol incubated at 25°C for 48 h or 5 days, respectively, was used for yeasts and moulds (Harmon *et al.*, 1992). *Pseudomonas* were determined by surface plating onto *Pseudomonas* isolation agar (Oxoid) which has high selectivity to *Pseudomonas* according to Difco (1990) followed by aerobic incubation at 25°C for 48 h.

2.4. Sensory evaluation

The sensory quality of each group of mango slices was evaluated by visual appearance, taste, flavor, color and texture acceptability. Samples of fruit pulp were presented in random order to 10 panelists for sensory evaluations. They were rated on a seven-point hedonic scale (The scores were: like extremely (7); like very much (6); like moderately (5); neither like nor dislike (4), dislike moderately (3); dislike very much (2); and dislike extremely (1).) (Hernández-Munóz *et al.*, 2008).

2.5. Statistical analysis

The experimental results were analyzed statistically by carrying analysis of variance (ANOVA) using SPSS 16.0 (SPSS Inc., USA) to demonstrate the difference between different treatments, and the calculations were performed at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

1. Physical and chemical analysis

1.1. Total soluble solids (TSS)

Total soluble solids (TSS) of mangoes increased significantly ($P < 0.05$) with storage time in all treatments as showed in Fig (1). This increasing during storage may be due to the change of starch to sugar under the effect of amylase enzyme and also for water loss (Arpaia *et al.*, 1985).

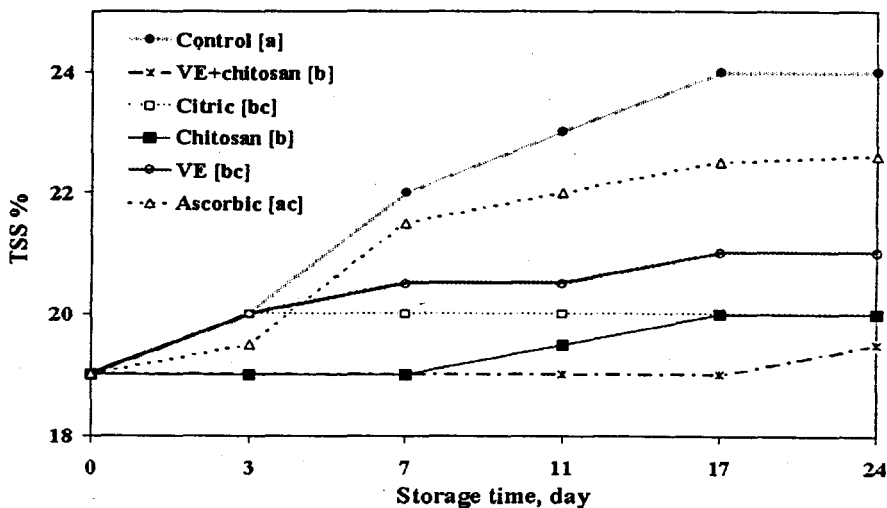


Fig. (1) Effect of chitosan coating and some immersion solutions on TSS of mango slices.

The initial TSS of uncoated mango slices was 19 % and increased rapidly to 24% at the end of storage (24 days) which could be attributed to fruit ripening development with time. These results suggested a delay in ripening and water loss under coating conditions. This was also found in the cellulose-based polysaccharide commercial coating on mangoes which showed a delay of ripening (Baldwin *et al.*, 1999).

Also it is evident that there was no significant difference ($P < 0.05$) between slices coated with VE +chitosan, citric, chitosan and VE. This is because these coats maintain the ripening of mango slices. On the contrary, the slices coated with ascorbic acid did not have a significant effect ($P < 0.05$) compared to uncoated control slices as declared in the statistical analysis letters assigned to each treatment shown in the legend of Fig. (1).

1.3. Firmness

The results of firmness of uncoated and coated mango slices are illustrated in Fig. (2a). Generally, all coating treatments maintained the firmness of mango slices significantly ($P < 0.05$) in spite of coating type. It was obvious from the results that mango slices treated with the formulation of VE +chitosan had the highest firmness during all time of storage. Chitosan containing VE formulation maintained the firmness more than chitosan or VE alone. This result was confirmed statistically as shown in letters assigned to each treatment in the legend of Fig. (2a). Also, this finding was observed by Han *et al.* (2004) who mentioned that the chitosan containing 0.2% VE coating showed better results for firmness than chitosan alone or chitosan containing 5% CG (calcium gluconate) coatings in strawberries. In general, chitosan coating worked as a film for reducing the respiration rate and ethylene production, controlling decay, and retention of firmness as indicated by Chien *et al.* (2007). On the other hand, control slices lost a lot of their firmness (73.19 %) this phenomenon might be explained as the control slices lacked the protected coat to maintain the cell wall constituents from degradation. The same trend was also reported by Plotto *et al.*, 2004 who mentioned that the soft texture of fruit and vegetables is due to many factors such as the loss in cell turgor pressure, vascular air and the degradation of cell wall constituents and polysaccharides.

1.4. Weight losses

The weight loss is a natural process of catabolism of horticultural products, catalysed by enzymes and is accelerated by cutting and slicing. This decrease in weight may be attributed to respiration and other senescence-related metabolic processes during storage (Watada and Qi, 1999). As a result of this fact, all mango slices suffered from weight loss but with different degree according to the coating used as shown in Fig. (2b). It was noticed that during the first seven days of storage, no significant difference in weight losses was observed between uncoated slices (2.93%) and the other coated sliced mango which were 1.93, 2.45, 2.16, 2.25 and 2.59% for VE +chitosan, citric, chitosan, VE and ascorbic acid respectively. After 11th days of storage the weight losses increased for all treatments but the highest weight loss was observed in uncoated control slices (14.87 %) at the end of storage. These results may be due to the leakage of juice from the pulp, rather than by the loss of water the same results were observed by

Sothornvit and Rodsamran, 2008 who reported that the warping provided an additional moisture barrier for whole mangoes. Meanwhile, the percentages of weight losses were 7.21, 9.45, 7.93, 9.11 and 9.6 % for VE +chitosan, citric, chitosan, VE and ascorbic coated slices respectively. All coated slices exhibited smaller loss in weight than uncoated control slices. This result was confirmed statistically as shown in the statistical analysis results assigned beside each treatment in the legend of Fig. (2b). Furthermore, slices coated with chitosan groups showed the lowest weight losses which represents one of the advantageous effects of chitosan coating on mango by reducing the leakage of juice (Chien *et al.*, 2007). Generally, coatings can retard ripening and water loss, and reduce decay (Baldwin *et al.*, 1997).

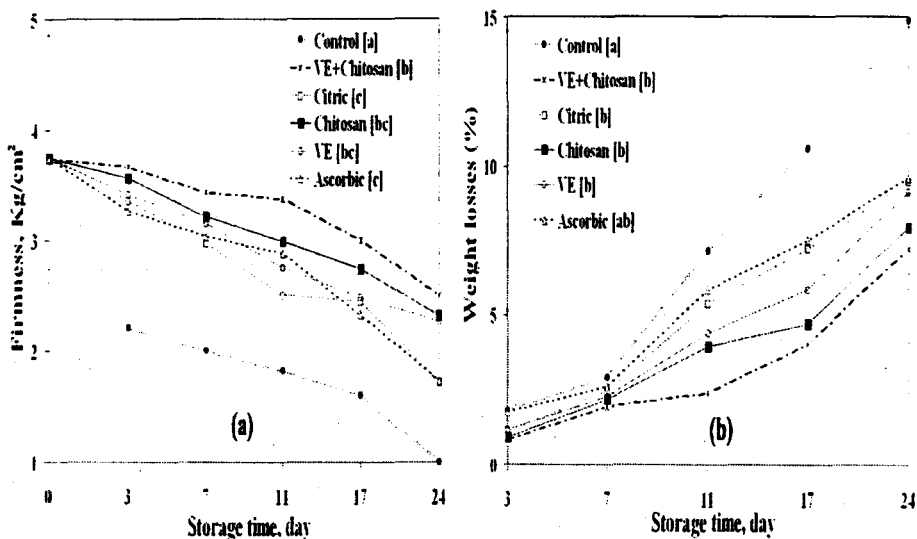


Fig (2) Effect of chitosan coating and some immersion solutions on (a) firmness and (b) Weight loss of mango slices.

1.5. Color change

Fruit color is very important property for consumers. Fig. (3b) showed the evolution of the redness (a^*) of the control and coated sliced mangoes. It is clear that the treated slices were lower than that of the control, but there was no significant difference ($P < 0.05$) between the uncoated control slices and the mango slices coated with ascorbic acid. On the other hand the slices coated with VE+Chitosan had the lowest a^* values at the end of storage and there was no significant difference between the control and the slices coated with chitosan and VE (alone or mixture).

Also, Fig. (3a) showed the change in L^* values of all mango slices during cold storage. The L^* values of the mango slices coated with VE or VE +chitosan were the highest (lighter color) than the L^* values of control at the end of storage time (darker color). These results may due to the uncoated slices contact directly with the O_2 . The same tendency was observed by Baldwin *et al.* (1999) who reported that the mango slices are very perishable because they lack protective pericarp and the pulp is very vulnerable to

dehydration, color breaking to dark and disease. This result was confirmed by statistical analysis which showed a significant difference ($P < 0.05$) between control and VE group.

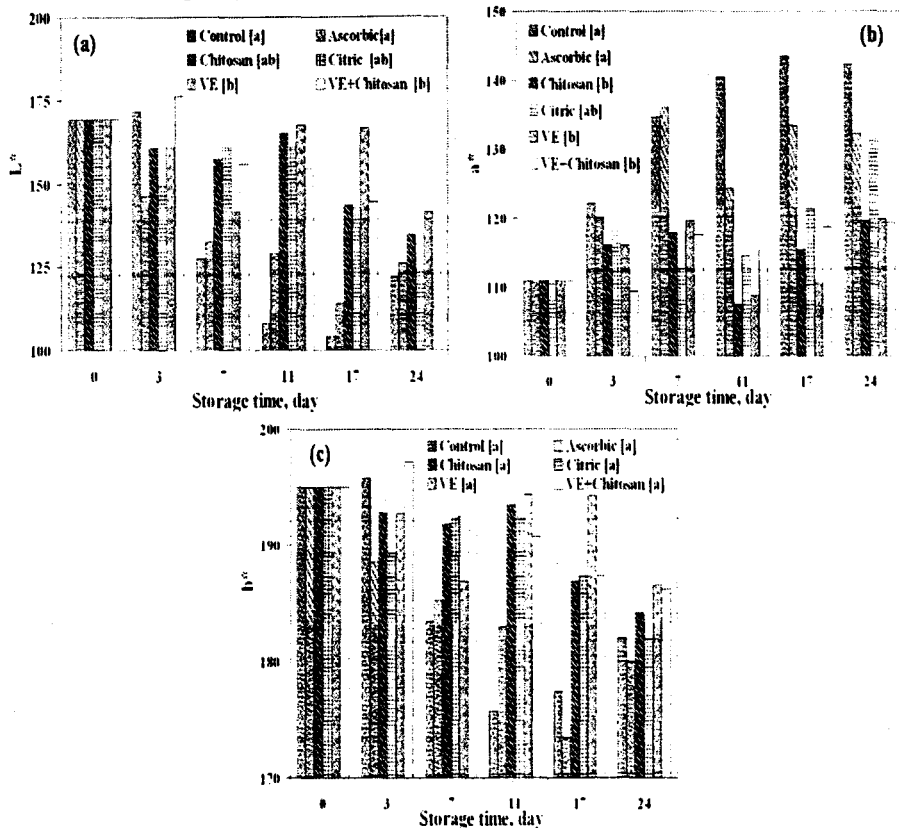


Fig. (3) Effects of chitosan coating and some immersion solutions on color components (L^* , a^* and b^*) of mango slices during cold storage.

In addition, the b^* value could also be used as the main indicator for flesh color change as shown in Fig. (3c). The b^* value also decreased significantly ($P < 0.05$) during storage from 195.08 value at zero time to 182.01, 180.01, 184.31, 181.96, 186.60 and 186.23 at the end of storage for control, ascorbic, chitosan, citric, VE, VE +chitosan respectively. There was no significant difference in b^* value among all samples. However, the slices coated with VE group and chitosan presented the highest quality of color during all time of storage.

To facilitate discrimination between different treatments used in coating mango slices, the normalized color components (r, g and b) were plotted against each other in a 3-D plot as shown in Fig. (4). Average values of r, g and b at the end of storage period were plotted in the 'rgb' color space.

The slices having the same color components tend to be projected in the same location in the 3-D plot.

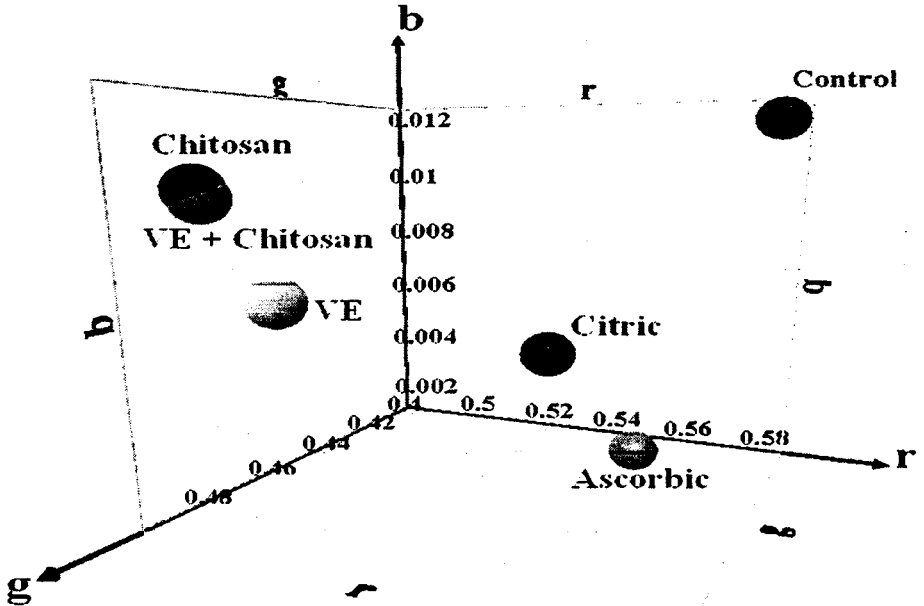


Fig. (4) Color component values in the 'rgb' color space at the end of storage time for mango slices treated with different coatings.

It is evident that distinctive color changes in r, g and b occurred between mango slices of different coating treatment. The uncoated control slices has the highest r value because of browning occurred under the effect of poly phenol oxidase (PPO). Mango slices treated by citric or ascorbic acid was found in the same location in the 'rgb' color space meaning that they have the same color features. This result was confirmed in the statistical analysis results as explained before. Similarly, mango slices treated by VE, chitosan and VE +chitosan occupied the same location in the 'rgb' color space indicating that these treatments have the same effect on color. In particular, slices coated by chitosan and VE+ chitosan had the same effect on color. It is obvious to figure out that slices treated by these two coats experienced little browning because they are projected in the blue side 'b' of the 'rgb' color space. Firmly speaking, the chitosan and/or VE + chitosan have the superior influence on the color of mango slices and it could be applied as an efficient edible coat.

2. Microbiological analysis

2.1. Total Bacterial Count

The results of total bacterial count found in uncoated and coated sliced mango are illustrated in Fig. (5). The total bacterial counts in coated mango slices were lower than that found in uncoated control slices despite

the coating type. In particular, chitosan coating effectively inhibited the growth of microorganisms. The data also reflected that the chitosan coating alone without any additives was more effective for hampering the growth of microorganisms compared to the other treatments. However, adding VE to chitosan formulation did not further affect the growth of microorganisms. Furthermore, the bioactive chitosan films potentially serve as a vehicle to incorporate and enhance the food value along with other additives such as flavoring, coloring, antioxidant and antimicrobial agents (Tharanathan, 2003). Also, from the previous data it was evident that the control samples had the worst quality after 17 days of storage ($> \log 5$); meanwhile slices treated with the other coatings after the same period were in a good quality condition until the end of storage.

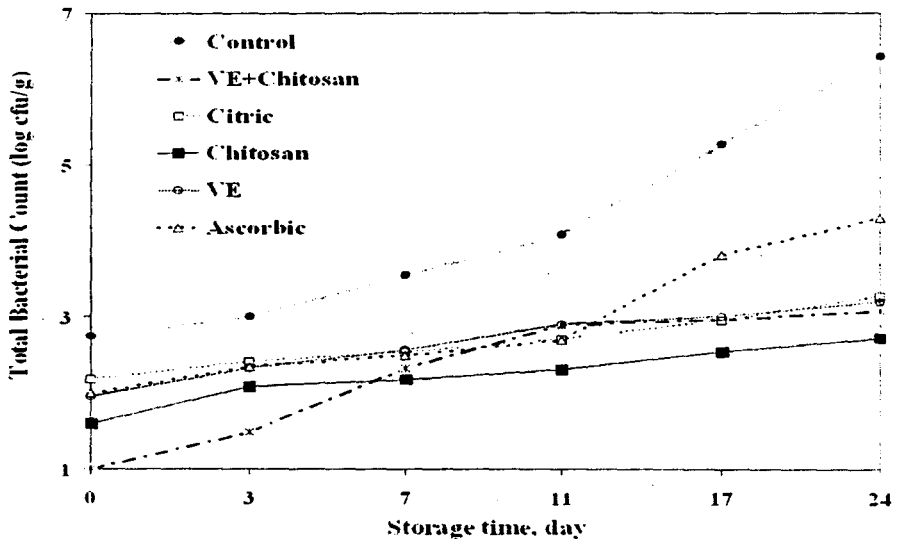


Fig (5) Effect of edible chitosan coating and some immersion solutions on the total bacterial count in the mango slices during cold storage.

2.2. Yeast and molds counts

At the end of storage period (24 days), the results tabulated in Table 1 showed that the highest count of yeast and molds (2.34 CFU/g) were found in uncoated control samples meanwhile mango slices coated with chitosan had the lowest count (1.3 CFU/g) of yeast and molds. This result was due to the antifungal effect of chitosan. These results are in agreement with results observed by El Ghaouth *et al.*, 1992 who reported that the chitosan as natural substance has proved to be effective in preventing fungal growth by directly interfering in or by activating certain biological processes. Also, Muñoz *et al.* (2009) concluded that chitosan offers a safe alternative to synthetic fungicides in postharvest anthracnose diseases and could be considered as a potential agrochemical of low environmental impact also they added that the International Commission on Natural Health Products recognized chitin (and

its derivatives) as a natural product for the 21st Century. Furthermore, chitosan was considered as generally recognized as safe substance by the FDA (Food and Drug Administration) based on the scientific procedures for use in foods. On the other hand, adding of VE to chitosan formulation did not enhance the efficiency for chitosan on the yeast and molds counts. This data were in agreement with Han *et al.* (2004) who found that the adding vitamin E into chitosan-based coatings did not significantly alter their antifungal and moisture barrier functions.

Table 1. Effect of chitosan coating and some immersion solutions on the yeast and molds count in mango slices during cold storage at 4°C±1.

Treatment	Storage time (days)					
	0	3	7	11	17	24
Control	0	1.9	1.95	2.04	2.2	2.34
VE +chitosan	0	1	1.3	1.3	1.48	1.6
Citric	0	1	1.3	1.3	1.48	1.6
Chitosan	0	0	0	0	1.3	1.3
VE	0	0	0	1	1.3	1.48
Ascorbic	0	0	1.95	1.478	1.84	1.95

2.3. Psychrotrophs bacterial count

The data presented in Fig. (6a) showed an increasing in psychrotrophs bacterial count throughout storage period. The psychrotrophic bacterial counts found in tested slices increased during storage from 2.18, 1.3, 1.9, 1.78, 1.7 and 1.3 CFU/g at the beginning of experiment to 5.44, 3.52, 4.57, 3.66, 4.39 and 4.98 CFU/g at the end of the storage time for control, VE +chitosan, citric, chitosan, VE and ascorbic acid respectively. It was clear that the psychrotrophs bacterial counts found in uncoated control slices were much higher compared to all other coating treatments from 0 day to the end of storage (24 days). Fortunately, all coatings were very effective for inhabiting the increasing of psychrotrophs bacterial count. Generally, slices treated with chitosan coating alone without any additives appeared to exhibit the lowest count than other coating formulations.

On the other hand, *Pseudomonas* bacterial counts illustrated in Fig. (6b) showed no difference between all coatings compared with uncoated control slices in the initial count. At the end of storage, *Pseudomonas* bacterial counts in uncoated control samples increased drastically to reach the highest value of 2.76 CFU/g at the end of storage. On the contrary, slices coated with chitosan groups gave the lowest *Pseudomonas* bacterial count. From all the previous data, it could be concluded that the antimicrobial activity of coating formulations is a very promising system for the future improvement of food quality and preservation during processing and storage and for extending the food shelf-life by reducing microbial colony. Chitosan has offered itself as a versatile and promising biodegradable polymer for food packaging. The same results were figured out by Dutta *et al.*, (2008) who reported that chitosan possesses immense potential as antimicrobial coating material owing to its antimicrobial activity and non-toxicity.

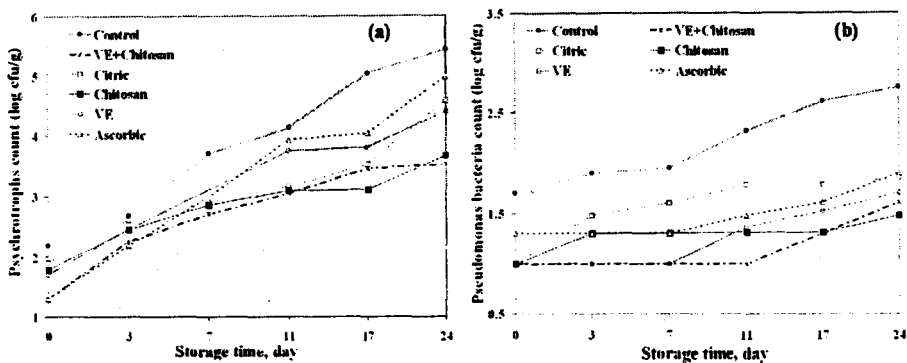


Fig. (6) Effect of chitosan coating and some immersion solutions on (a) psychrotrophic bacterial count and (b) *Pseudomonas* Spp. count in mango slices during cold storage.

3. Sensory evaluation

The sensory evaluation of the uncoated as well as coated mango slices were assessed in terms of color, taste, appearance, aroma and texture as shown in Fig. (7). In essence, color change was observed on the surface of fresh mangoes due to enzymatic browning. Cutting allows polyphenoloxidase (PPO) to come in contact with phenolic compounds and O_2 and leads to tissue browning. Generally, coatings or films reduce exposure of fruit and vegetables to O_2 and reduce fruit browning. Both the taste and the color scores of mango pulp fall quickly during storage. Chitosan coating delayed the drop in sensory quality and extends the shelf life. Both the control and the coated mango slices were still commercially satisfactory after 11th days of storage. However, after only 11 days of storage; the uncoated control slices became unacceptable whereas a good quality of the coated slices by chitosan + VE, chitosan or citric acid was retained acceptable until the end of storage (24 days). It was evident from Fig. (7) that the mango slices coated with chitosan + VE formulation had a great score in the test panel and look like as if it is in the first day of storage. Based on this trend, Chien *et al.* (2007) reported that the chitosan coating on sliced mango improved its quality and prevented surface cracking and the leaking of juice. Also, Baldwin *et al.* (1999) observed that the coatings with polysaccharide-based and carnauba wax created modified atmospheres, reduced decay, and improved appearance of mango by imparting a subtle shine; but only the polysaccharide coating delayed ripening and increased concentrations of flavor volatiles.

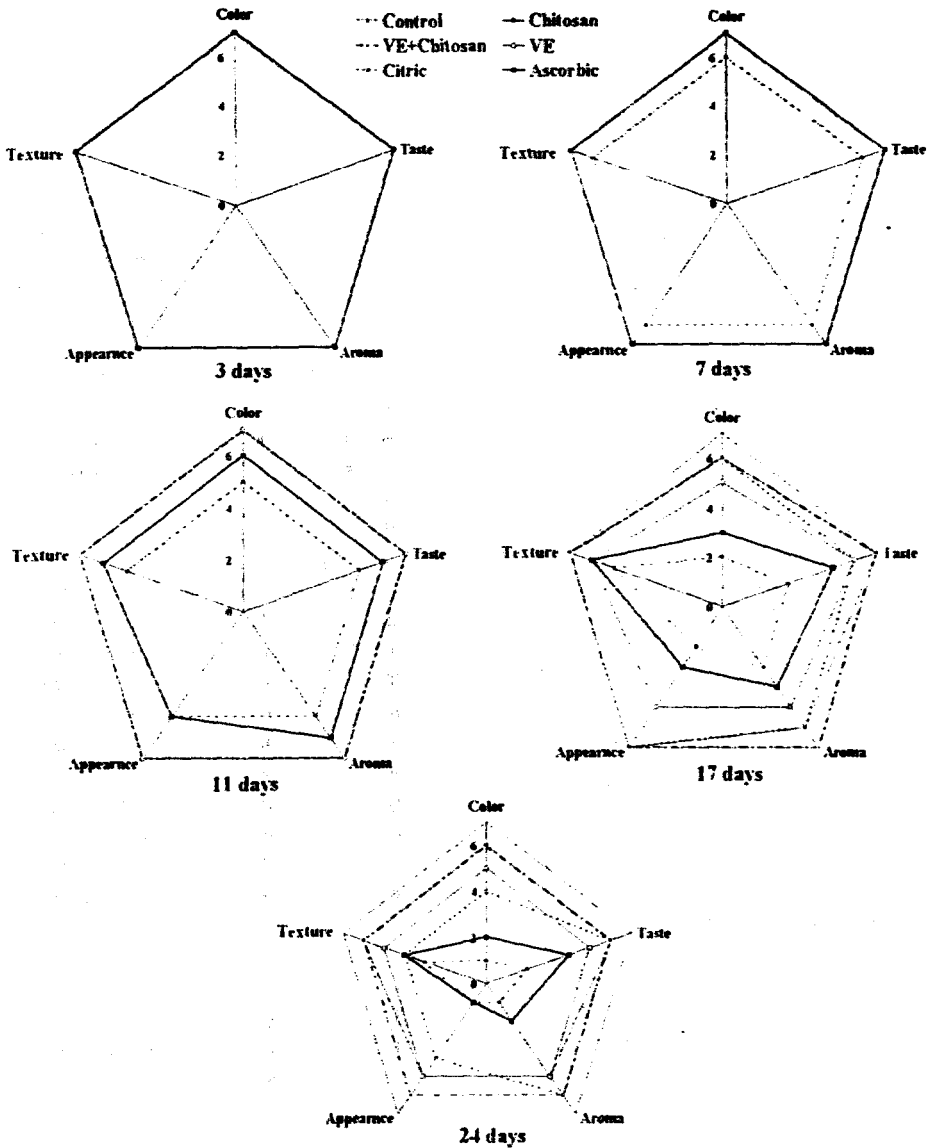


Fig. (7). Effect of chitosan coating and some immersion solutions on the sensory quality of mango slices at different storage periods.

CONCLUSION

Different treatments of aqueous solutions of 1% chitosan; 2g/l citric acid, 200ppm vitamin E (VE), 200ppm ascorbic acid and 200ppm vitamin E + 1% chitosan were tested for extending the shelf life of minimally processed

mango slices. Mangos of superior quality were cut to equal slices, treated with different coatings, placed in plastic trays, over-wrapped with low density polyethylene (LDPE) film and then stored at 4°C (± 1). The results revealed that tested coatings have a great potential to extend the shelf-life and quality of mango slices by preventing changes in aroma, taste, texture and appearance compared to the control. Color change was observed on the surface of fresh mango slices due to enzymatic browning. Cutting allows poly phenoloxidase (PPO) to come in contact with phenolic compounds and O₂, and leads to tissue browning. Generally, coatings reduce exposure of fruit and vegetables to O₂ and reduce fruit browning. Chitosan containing VE formulation maintained the firmness more than chitosan or VE alone. On the other hand, adding VE to chitosan formulation did not enhance the efficiency of chitosan in preventing the microbial cell load.

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تأثير الشيتوزان و بعض محاليل الغمر على الجودة والعمر التخزينى لسرايح
المانجو
جمال على عبد العال، أمال عبد الفتاح جاب الله ، رفعت أمين طه و
نها السيد مرسى
قسم الصناعات الغذائية - كلية الزراعة - جامعة قناة السويس

تمت هذه الدراسة على سرايح المانجو المقطعة يدويا حيث تم غمرها باستخدام الشيتوزان بتركيز ١ % كغلاف قابل للأكل و بعض محاليل الغمر (٢ جرام/لتر حمض سيترك ، ٢٠٠ جزء فى المليون حمض أسكوربيك، ٢٠٠ جزء فى المليون فيتامين هـ، خليط من ١% شيتوزان + ٢٠٠ جزء فى المليون فيتامين هـ) ثم تعبنتها فى أطباق وتغليفها بأغلفة بلاستيكية مصنعة من مادة البولى اثيلين منخفض الكثافة ثم حفظها على درجة حرارة الثلجة (٤± ١). وقد تم تحديد الجودة النهائية لهذه المنتجات بعد فترات تخزين مختلفة من خلال دراسة بعض خصائصها الكيماوية والطبيعية (المواد الصلبة الذائبة الكلية، الصلابة، فقد الوزن)، جودتها الميكروبيولوجية (العدد الكلى للميكروبات، عدد الميكروبات المحبة للبرودة، عدد الخمائر والفطريات وعدد بكتريا *Pseudomonas*) وخواصها الحسية (الطعم، الرائحة، اللقوام، اللون، المظهر). ولقد أظهرت النتائج أن جميع معاملات الغمر قد أدت لتقليل فقد الوزن مقارنة بالكنترول (بدون معاملة) وكذلك أدت لتحسين الصلابة بدرجة معنوية مقارنة بالكنترول. كما أظهرت النتائج أن استخدام الشيتوزان بمفرده أو مخلوطا مع فيتامين هـ فى تغطية سرايح المانجو قد أدى الى حفظ صلابة سرايح المانجو مقارنة بباقي المعاملات الأخرى. وكان لإستخدام الشيتوزان بمفرده أو مخلوطا مع فيتامين هـ دورا رئيسيا فى تحسين اللون مقارنة بباقي المعاملات الأخرى. ومن ناحية الجودة الميكروبية فقد أدت جميع معاملات الغمر الى تقليل العدد الكلى للميكروبات، عدد الميكروبات المحبة للبرودة، عدد بكتريا *Pseudomonas* SSp، عدد الخمائر والفطريات. وبصفة عامة فإن إضافة فيتامين هـ للشيتوزان أدى إلى تحسين الخواص الحسية لسرايح المانجو فى حين أنه لم يؤثر بدرجة واضحة على جودتها الميكروبيولوجية.