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# Effect of Some Postharvest Treatments on Browning Inhibition of Fresh-Cut Eggplant

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**Abstract:** Eggplant fruits (*Solanum melongena* L. Sawad El Laeil hybrid) were obtained from experimental Farm for Central Lab. For Agric. Climate in Boselli Research Station, Rashid, Beheira governorate during two successive seasons of 2016 and 2017 summer seasons. Eggplant fruits were harvested at the proper stage of marketing and then transported to laboratory of Handling of Vegetable Crops Department, Horticulture Research Institute, Giza governorate. Good eggplant fruits were cut into rings (1.5 cm thickness and the weight was about 40-50g) and then dipped into 50 ppm sodium hypochlorite for 30 second and rinsed with distilled water and then dipped in the following treatments (chitosan at 1% or 2% for 3 min, carboxy methyl cellulose at 1% or 2% for 3 min, gibberellic acid at 100 ppm or 200 ppm for 3 min and distilled water represented as control). All treatments were dried and packed in trays sealed with polypropylene film and stored at 5°C and 95% relative humidity for 12 days. The obtained results revealed that fresh-cut eggplant coated with carboxy methyl cellulose (CMC) at 1% or 2% were the most effective treatments for controlling the discoloration of the tissues (lowest a* value) as compared with untreated control which had higher a* value showed more darker and brownish. Chitosan at 2% treatment provided the lowest count in all types of microorganisms. Fresh-cut eggplant dipped in carboxy methyl cellulose at 2% was the most effective treatment in reducing weight loss percentage, color change of cut surface, polyphenol oxidase activity, total microbial count and maintained quality attributes (firmness and total phenols) and gave good appearance after 12 days of storage at 5°C.

**Key words:** Fresh-cut eggplant · Carboxy methyl cellulose · Chitosan · Gibberellic acid · Browning Inhibition · Quality and cold storage

## INTRODUCTION

The consumption of minimally processed food products including ready-to-eat or ready-to-use has increased worldwide during the last decade due to their convenience, freshness and improved quality [1]. Ready-to-use products typically involve peeling, slicing, dicing or shredding prior to packaging and storage [2]. These products have an active metabolism that can result in deteriorative changes, such as increased respiration and ethylene production and in association with an increase in the rate of other biochemical reactions are responsible for changes in color, flavor, texture, appearance and nutritional quality and increased microbiological contamination [3, 4].

Enzymatic browning (EB) does not occur in intact plant cells since phenolic compounds in cell vacuoles are separated from the PPO which is present in the cytoplasm. The rate of EB in fruit and vegetables is governed by the active PPO and phenolic content in tissue, pH, temperature and O2 availability within in the tissue [5]. Fresh-cut eggplants are one of the most perishable vegetables. Once the product is cut, quick enzymatic browning appears due to the oxidation of the phenolic compounds [6]. The main problem for diced eggplant is oxidation caused by polyphenol oxidase (PPO, EC 1.14.18.1), in the presence of oxygen, an enzyme producing pigments responsible for the undesirable dark color which makes the product not suitable to market and softening promoted by pectin methylesterase (PME, EC 3.1.1.11) and polygalacturonase (PG, EC 3.2.1.15) [7, 8, 9].

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Polyphenol oxidase catalyses the hydroxylation of monophenols to o-diphenols (cresolase activity) and the oxidation of o-diphenols to o-quinones (catecholase activity), which represent the main reaction product. Subsequent reactions of the quinones lead to melanin accumulation, which is the brown or black pigment associated with "browning" in plant tissue reactions. PPO is located in cell organelles such as chloroplasts, mitochondria and peroxisomes where it is firmly bound to the membrane or soluble [10, 11].

It is necessary to use some technique treatments (carboxy methyl cellulose, chitosan and gibberellic acid) as a postharvest treatment that conjunction with low temperature to extend shelf life and browning control of fresh-cut eggplant.

Edible coating is a method to extend shelf life of products with minimum processing. Edible coating is a film of edible materials on food via wrapping, dipping, brushing or spraying to create a selected barrier to gas, steam and dissolved materials transfer [12]. Coatings have the potential to reduce moisture loss, restrict oxygen entrance, lower respiration, retard ethylene production, seal in flavor volatiles and carry additives (such as antioxidants) that retard discoloration and microbial growth [13]. Edible coatings and films via creating a semi-permeable membrane to gases and water steam and reduction of enzyme browning, reduced respiration and water loss extend shelf life of fresh-cuts [14].

Carboxy methyl cellulose (CMC) has widely been used in food application. One of this function is as edible coating for fruits or vegetable to retard dehydration, providing a selective barrier to moisture, oxygen and carbon dioxide, suppressing respiration, improving textural quality and helping to retain volatile flavor compounds [15]. So it can prolong shelf life of fresh fruits during transportation and storage before consumption. Soaking of eggplant rings in CMC and water blanching under the best conditions found reduced oil uptake and increased hardness and sensory quality of fries, without modifying color, moisture content or sensory acceptability.

Chitosan has been reported to increase the potential of the reactive oxygen species scavengers, leading to increased contents of phenolic compounds and antioxidants [16]. Also, treatment with different concentrations of chitosan has also been reported to activate the antioxidant enzymes catalase (CAT), superoxide dismutase (SOD) and peroxidase (POD), which are an important part of the antioxidant potential during storage, in tomato and fresh-cut eggplant [17, 18]. Chitosan has attracted attention as a potential food preservative of natural origin due to its antimicrobial activity against fungi, yeast and bacteria and can improve the storability of perishable foods by modifying the internal atmosphere as well as decreasing the transpiration losses [19, 20].

Gibberellic acid (GA) is a vegetarianism hormone which produced by late leaves and growing caps in the roots and stems. It has many applications on vegetable crops one of them is extend of the storage periods by delaying the senescence. GA has been used to prevent deterioration and browning of fresh–cut fruits and vegetables [21, 22].

The present study investigated the effects of carboxy methyl cellulose, chitosan and gibberellic acid coating as postharvest treatment on quality attributes and browning control of fresh-cut eggplant during cold storage.

## MATERIALS AND METHODS

Eggplant fruits (*Solanum melongena* L.) Sawad El Laeil hybrid were harvested at the proper stage of marketing on 4$^{th}$ and 6$^{th}$ of September in 2016 and 2017 summer season, respectively from Experimental Farm for Central Lab. for Agric. Climate in Boselli Research Station, Rashid, Beheira governorate to investigate the effect of some postharvest treatments such as Carboxy methyl cellulose (CMC), chitosan and gibberellic acid (GA) on quality and browning inhibition of fresh-cut eggplant during storage. Eggplant fruits were transported immediately to the laboratory of Handling of Vegetable Crops Department, Horticulture Research Institute, Agriculture Research Center, Giza Governorate, then selected for uniform size, color and maturity degree without any physical injury, fungal and bacterial diseases. The fruits were washed and surface sterilized in 150 ppm sodium hypochlorite solution for 5 min, rinsed with distilled water, dried in a well ventilated room. All used steel sharp knives, cutting boards and any equipment which come into contact with the fresh-cut eggplants were sanitized by immersion in 1000 mg/L chlorine for 30 min before the start of cutting. The eggplant fruits were cut into rings (approximately 1.5 cm thickness and the weight was 40-50g). Each rings soaked into 50 ppm sodium hypochlorite for 30 second and rinsed with distilled water. Seven different treatments were applied as follow: (chitosan at 1% or 2% for 3 min, CMC at 1% or 2% for 3 min, GA 100 ppm or 200 ppm for 3 min and distilled water represented as control).

**Preparation of Chitosan, (CMC) Solution and GA:** Chitosan is a commercial product, it includes chitosan 90-95% (2-Amino-2-deoxy-beta-D-glucosamine) [23]. Chitosan was bought from El-Gomhouria Company, Egypt. Chitosan coating at 1% or 2% was prepared by dissolving 10g or 20g chitosan powder in 1000 ml of distilled water, respectively and homogenized by magnetic stirrer. Glycerol (1.5% W/V) was added into the mixture as a plasticizer.

Carboxy methyl cellulose (CMC) was bought from Technogene Company, Egypt. CMC coating at 1% or 2% was prepared by dissolving 10 g or 20 g of CMC powder in a water ethyl alcohol mixture (2:1) at 75°C under the high speed mixer (900 rpm) for 15 min. then, glycerol (1.5% W/V) were added and the solution was stirred for another 10 min. under the same conditions.

Gibberellic acid (GA) at the concentrations of 100 ppm and 200 ppm was prepared by dissolving 0.1 or 0.2 g powder in 1000 ml of distilled water, respectively and homogenized by magnetic stirrer.

All treatments of fresh-cut eggplant were dried at ambient temperature under sterilized condition and packed in trays sealed with polypropylene film 30 µm thickness and each bag was approximately 200g represented as experimental unit (EU). Eighteen EU were prepared for each treatment. Samples were arranged in complete randomized design. All treatments were placed inside carton boxes (40 × 30 ×12.5 cm) and stored at 5°C and 95% RH, for 12 days. Samples of 3 replicates (EU) were randomly taken and examined immediately after treatment and at two days intervals for the following properties:

**Weight Loss (%):** Weight of each sample of the three replication of each treatment was recorded after harvest and after every 2 days of storage period. Cumulative weight losses were expressed as percentage loss of original weight [24].

**General Appearance:** Was determined according to the scale of scoring system 9: Excellent, 7: good, 5: fair, 3: poor and 1: unsalable [25]. Which depends on morphological defects such as shriveling, color change (browning) and pathological defects.

**Flesh Color Change:** Color measurements were made periodically with a Minolta chromameter (Model CR-300). color parameters, L*, a* and c*. Each measurement was taken randomly at two different locations of each sample of fresh-cut eggplant rings [26].

**Fruit Firmness:** Firmness was measured by a hand pressure tester (Italian model) expressed in $kg/cm^2$.

**Polyphenol Oxidase Activity (PPO):** Polyphenol Oxidase Activity (PPO) was extracted using the methods of Dogan *et al*. [27].

**Total Phenols Contents:** Total phenols contents were extracted using the methods of Kahkonen, *et al.* [28] and determined using the method of Iavnova *et al.* [29].

**Total Microbial Count Method:** Total microbial count method was accordingly referred to Luna-Guzmán and Barrett [30]. The microbial counts were expressed as log10 (cfu $g^{-1}$).

**Statistical Analysis:** The experiment was factorial with 2 factors in complete randomized design (CRD) with 3 replicates. Comparison between means was evaluated by Duncan's Multiple Range Test at 5% level of significance. The statistical analysis was performed according to Snedecor and Cochran [31].

## RESULTS AND DISCUSSION

**Weight Loss:** Data in Table (1) show the effect of postharvest treatments on weight loss percentage of fresh-cut eggplant during storage at 5°C. Data revealed that there were significant increases in weight loss percentage with the prolongation of storage period during the two seasons. The weight loss is a natural consequence of the catabolism of horticultural products. The loss in weight may be attributes to respiration and other senescence related metabolic processes during storage [32]. Similar results were obtained by Mohamed *et al.* [33] on fresh-cut eggplant.

Concerning the effect of postharvest treatments, data revealed that there were significant differences among treatments in weight loss percentage during storage. All treatments reduced weight loss % during storage as compared with untreated control. Moreover, fresh-cut eggplant dipped in solution of carboxy methyl cellulose 2% or 1% were the most effective treatment in reducing weight loss% during storage with no significant differences between them in the first season followed by chitosan at 2%. Gibberellic acid at 100 ppm or 200 ppm treatments were less effective in this concern, while untreated control gave the highest values of weight loss%. These results were achieved in the two seasons

Table 1: Effect of inhibitors browning and storage periods on weight loss % of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| | Storage periods (days) | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatments | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
| | | | | 2016 | | | |
| Chitosan 1% | 0.21kl | 0.42i-l | 0.47i-l | 0.57g-l | 0.79g-j | 1.07e-h | 0.59D |
| Chitosan 2% | 0.13kl | 0.27j-l | 0.29j-l | 0.34j-l | 0.39i-l | 0.56h-l | 0.33E |
| GA 100 ppm | 0.80g-j | 1.41d-f | 1.48c-e | 1.72b-d | 1.81b-d | 1.97bc | 1.53B |
| GA 200 ppm | 0.65g-k | 1.03e-h | 1.10e-g | 1.35d-f | 1.53b-e | 1.65b-d | 1.22C |
| CMC 1% | 0.08l | 0.19kl | 0.22kl | 0.24kl | 0.29j-l | 0.39i-l | 0.24EF |
| CMC 2% | 0.05l | 0.10l | 0.16kl | 018kl | 0.21kl | 0.28j-l | 0.16F |
| Control | 0.89f-i | 1.68b-d | 1.74b-d | 1.86b-d | 2.05ab | 2.52a | 1.79A |
| Mean | 0.40E | 0.73D | 0.78CD | 0.89BC | 1.01B | 1.20A | |
| | | | | 2017 | | | |
| Chitosan 1% | 0.24r-v | 0.51n-q | 0.56m-p | 0.80k-m | 0.98jk | 1.55g-i | 0.77D |
| Chitosan 2% | 0.14s-v | 0.30p-v | 0.37o-t | 0.68l-n | 0.81k-m | 0.93j-l | 0.54E |
| GA 100 ppm | 0.85j-l | 1.47hi | 1.59f-i | 1.81d-g | 1.91de | 2.26bc | 1.65B |
| GA 200 ppm | 0.71l-n | 1.08j | 1.34i | 1.60f-h | 1.66e-h | 2.06cd | 1.41C |
| CMC 1% | 0.11uv | 0.21s-v | 0.32p-u | 0.47n-r | 0.52n-q | 0.58m-o | 0.37F |
| CMC 2% | 0.06v | 0.12t-v | 0.21s-v | 0.27q-v | 0.31p-v | 0.37o-s | 0.22G |
| Control | 0.93j-l | 1.75e-g | 1.83d-f | 2.25bc | 2.34b | 2.90a | 2.00A |
| Mean | 0.43F | 0.78E | 0.89D | 1.12C | 1.22B | 1.52A | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose.

and were in agreement with Miran and Javanmard [18] for carboxy methyl cellulose, Helaly *et al.* [34] for chitosan and GA.

Carboxy methyl cellulose coatings are effective physical barrier to moisture loss and slower rates of weight loss in coated fruits because of the cover features for gas diffusion of stomata, the organelles that regulate the transpiration process and gas exchange between the fruit and the surroundings [15]. Also, the CMC edible coating provides a semi permeable barrier to $O_2$, $CO_2$, $H_2O$ and moisture transfer slowing down fruit respiration [35]. Thereby, weight loss reducing during storage.

The favorable effect of chitosan treatment in reducing weight loss may be due to chitosan coating forms a layer of semi-transparent to smooth the pericarp surface and can be used as protective barrier to reduce respiration and transpiration rates through fruit surface [27, 36]. Also, Shiri *et al*. [37] found that chitosan coating reduced weight loss during storage as it enables epidermal tissues to control water loss and reduce respiratory activity, barrier to water vapor, reducing moisture loss and delaying fruit dehydrations [35].

Minimizing weight loss from GA during storage may be related to a part role played by in lowering the respiration rate [38]. It's striking effect in delaying the senescence [39]. Increasing the content of cuticle and sustain the integrity of membranes, which reduce the water loss and increasing the cell–wall thickness that protect the fruits from the fungal infection [38, 40, 41].

In general, the interaction between postharvest treatments and storage periods was significant effect on weight loss percentage in the two seasons. After 12 days of storage, the lowest value of weight loss was recorded from fresh-cut eggplant dipped in carboxy methyl cellulose 2% or 1% with no significant differences between them in the two seasons while the highest ones were obtained from untreated control.

**General Appearance:** Data in Table (2) show that general appearance (score) of fresh-cut eggplant was decreased with the prolongation of storage period. These results were in agreement with those obtained by Mohamed *et al.* [33] on fresh-cut eggplant. The decreases in general appearance during storage might be due to shriveling, color change and decay [42].

Concerning the effect of postharvest treatments, data revealed that fresh-cut eggplant treated with all treatments had significantly the highest score of appearance as compared with untreated control, except GA at 100 ppm. However, fresh-cut eggplant dipped in carboxy methyl cellulose 2% or 1% and chitosan 2% were the most effective treatments for maintaining general appearance with no significant differences between them in the two seasons followed by chitosan 1%. Gibberellic acid at 200 ppm was less effective in this concern, while untreated control or GA at 100 ppm treatment recorded the lowest value of general appearance. These results were achieved in the two seasons and were in agreement with

Table 2: Effect of inhibitors browning and storage periods on general appearance score of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| | Storage periods (days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
| | | | | 2016 | | | | |
| Chitosan 1% | 9.00a | 9.00a | 9.00a | 9.00a | 7.67a-c | 7.00a-d | 5.67c-f | 8.05B |
| Chitosan 2% | 9.00a | 9.00a | 9.00a | 9.00a | 8.33ab | 7.67a-c | 6.33b-e | 8.33AB |
| GA 100 ppm | 9.00a | 9.00a | 9.00a | 6.33b-e | 5.00d-g | 4.33e-g | 3.67fg | 6.62D |
| GA 200 ppm | 9.00a | 9.00a | 9.00a | 7.67a-c | 6.33b-e | 5.67c-f | 4.33e-g | 7.29C |
| CMC 1% | 9.00a | 9.00a | 9.00a | 9.00a | 9.00a | 7.67a-c | 7.00a-d | 8.52AB |
| CMC 2% | 9.00a | 9.00a | 9.00a | 9.00a | 9.00a | 8.33ab | 7.67a-c | 8.71A |
| Control | 9.00a | 9.00a | 9.00a | 5.67c-f | 4.33e-g | 3.67fg | 3.00g | 6.24D |
| Mean | 9.00A | 9.00A | 9.00A | 7.95B | 7.10C | 6.33D | 5.38E | |
| | | | | 2017 | | | | |
| Chitosan 1% | 9.00a | 9.00a | 9.00a | 8.33ab | 7.00a-d | 6.33b-e | 5.00d-g | 7.67B |
| Chitosan 2% | 9.00a | 9.00a | 9.00a | 9.00a | 7.67a-c | 7.00a-d | 5.67c-f | 8.05AB |
| GA 100 ppm | 9.00a | 9.00a | 9.00a | 5.67c-f | 4.33e-h | 3.67f-h | 3.00gh | 6.24D |
| GA 200 ppm | 9.00a | 9.00a | 9.00a | 9.00a | 5.67c-f | 5.00d-g | 3.67f-h | 6.90C |
| CMC 1% | 9.00a | 9.00a | 9.00a | 9.00a | 8.33ab | 7.67a-c | 7.00a-d | 8.43AB |
| CMC 2% | 9.00a | 9.00a | 9.00a | 9.00a | 9.00a | 8.33ab | 7.67a-c | 8.71A |
| Control | 9.00a | 9.00a | 8.33ab | 5.00d-g | 3.67f-h | 3.00gh | 2.33h | 5.76D |
| Mean | 9.00A | 9.00A | 8.90A | 7.57B | 6.52C | 5.86D | 4.91E | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose.

Miran and Javanmard [18] and Yinzhe and Shaoying [43] for carboxy methyl cellulose and Ardakani and Mostofi, [41] for chitosan.

The decreasing of general appearance may be due to carboxy methyl cellulose or chitosan coating acts as a semipermeable barrier on the surface of fruit and vegetables against oxygen, carbon dioxide and moisture, thereby reducing respiration, water loss, respiratory activity and degradation by enzymes and microbial rot of fruits, counteracting the dehydration and shrinkage of the fruit and ethylene production and maintaining the overall quality [18, 34].

Gibberellic acid maintaining postharvest quality by delaying the loss of chlorophyll and consequently retarded the appearance of brown color [44].

In general, the interaction between postharvest treatments and storage periods, data revealed that fresh-cut eggplant dipped in carboxy methyl cellulose 2% did not show any changes in general appearance till 10 days of storage and gave good appearance at the end of storage period (12 days at 5°C). While, carboxy methyl cellulose 1% treatment rated good appearance at the same period. Chitosan at 2% or 1% gave good appearance after 10 days of storage at 5°C. On the other hand, untreated control had the poor appearance after 12 days of storage at 5°C.

**Color (L Value):** Changes in lightness (L value) were observed during storage compared to initial value. Lightness of fresh-cut eggplant was affected by storage time. A decrement in L value was detected by prolonging the storage period (Table 3), indicating that the browning process of cut surface developed and reached darker with storage. These results were achieved in the two seasons and in agreement with Mohamed *et al.* [33] on fresh-cut eggplant. Ardakani and Mostofi [41] showed that decreasing in L value relates to water loss in fruit.

Concerning the effect of postharvest treatments, the best results were observed for fresh-cut eggplant coated with CMC at 1% or 2% and chitosan at 2% being the most effective treatment in maintaining the L values, resulted lighter color (high L value) with no significant differences between them in the two seasons. The other treatments were less effective in this concern, while fresh-cut eggplant treated with distilled water (control) or GA at 100 ppm had darker color (low L value) during storage with no significant differences between them in the two seasons. These results were agreement with Miran and Javanmard [18] for carboxy methyl cellulose, Ardakani and Mostofi [41] chitosan coated lightened slightly as evidenced by increasing values of L value and Helaly *et al.* [34] for GA and chitosan.

**Color (A* Values):** As shown in Table (4) indicated that continuous increasing in a* values (brownish) of fresh-cut eggplant as the storage period was prolonged. These results were true in the two seasons and in agreement with Ali *et al.* [20] and Mohamed *et al.* [33].

Table 3: Effect of inhibitors browning and storage periods on L value of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| Treatments | Storage periods (days) 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | | 2016 | | | | |
| Chitosan 1% | 84.37a | 80.66a-e | 80.31a-f | 77.31a-j | 74.78c-k | 75.15c-l | 66.57k-n | 77.02 B |
| Chitosan 2% | 84.37a | 81.60a-d | 80.73a-e | 78.20a-h | 77.60a-i | 77.21a-i | 67.27j-n | 78.14AB |
| GA 100 ppm | 84.37a | 77.60a-i | 75.50a-j | 74.35c-k | 71.02e-m | 70.08f-m | 62.36mn | 73.61D |
| GA 200 ppm | 84.37a | 80.20a-e | 78.73a-g | 75.88a-j | 73.85c-l | 72.58d-l | 65.04l-n | 75.81C |
| CMC 1% | 84.37a | 82.87a-c | 81.96a-c | 79.93a-f | 78.82a-g | 77.93a-i | 69.13h-n | 79.29A |
| CMC 2% | 84.37a | 84.20a | 83.93ab | 82.25a-c | 80.12a-f | 78.71a-g | 70.74g-m | 80.62A |
| Control | 84.37a | 77.05a-i | 75.01b-k | 71.98e-m | 69.86g-n | 68.99i-n | 61.12n | 72.63D |
| Mean | 84.37A | 80.59B | 79.45BC | 77.12CD | 75.15DE | 74.37E | 66.03F | |
| | | | | 2017 | | | | |
| Chitosan 1% | 82.15a | 78.03a-d | 77.73a-d | 72.94a-h | 71.84a-j | 70.83bk | 64.16j-m | 73.95C |
| Chitosan 2% | 82.15a | 79.14a-c | 78.77a-d | 76.34a-f | 75.04a-g | 74.78a-h | 64.41i-m | 75.80AB |
| GA 100 ppm | 82.15a | 74.84a-h | 73.70a-i | 71.78b-k | 69.50d-l | 68.33e-l | 60.75lm | 71.58DE |
| GA 200 ppm | 82.15a | 76.04a-e | 75.26a-f | 72.47a-j | 71.70b-k | 70.42c-k | 61.83k-m | 72.83D |
| CMC 1% | 82.15a | 80.15ab | 79.09a-c | 77.94a-d | 76.66a-f | 75.41a-g | 65.68h-m | 76.73AB |
| CMC 2% | 82.15a | 82.13a | 82.01a | 80.28ab | 78.25a-d | 76.50a-f | 68.22e-l | 78.51A |
| Control | 82.15a | 74.46a-h | 73.17a-j | 69.73d-l | 67.67f-m | 66.27g-m | 58.40m | 70.27E |
| Mean | 82.15A | 77.82B | 77.10BC | 74.49CD | 72.95DE | 71.79E | 63.35F | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose.

Table 4: Effect of inhibitors browning and storage periods on color (a*) of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| Treatments | Storage periods (days) 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | | 2016 | | | | |
| Chitosan 1% | 0.73s | 2.38q | 4.28n | 6.23kl | 7.02hi | 7.88fg | 8.32e | 5.26D |
| Chitosan 2% | 0.73s | 1.84r | 3.95n | 5.93l | 6.44jk | 7.01hi | 7.55g | 4.78E |
| GA 100 ppm | 0.73s | 3.94n | 5.98l | 7.09h | 8.11ef | 9.14c | 9.58b | 6.37B |
| GA 200 ppm | 0.73s | 3.15op | 5.17m | 6.68ij | 7.59g | 8.49de | 8.81cd | 5.80C |
| CMC 1% | 0.73s | 1.64r | 3.37o | 4.32n | 5.01m | 5.92l | 6.09kl | 3.87F |
| CMC 2% | 0.73s | 1.43r | 2.84p | 3.41o | 3.95n | 4.17n | 4.78m | 3.05G |
| Control | 0.73s | 4.02n | 6.22kl | 7.73fg | 9.03c | 9.95b | 10.62a | 6.90A |
| Mean | 0.73G | 2.63F | 4.54E | 5.91D | 6.74C | 7.51B | 7.96A | |
| | | | | 2017 | | | | |
| Chitosan 1% | 0.78w | 2.45tu | 4.35pq | 6.29lm | 7.09jk | 7.94g-i | 8.39e-h | 5.33D |
| Chitosan 2% | 0.78w | 1.91uv | 4.05qr | 5.98m | 6.51k-m | 7.08jk | 7.62ij | 4.85E |
| GA 100 ppm | 0.78w | 4.02qr | 6.07lm | 7.16jk | 8.21f-i | 9.23cd | 9.66bc | 6.45B |
| GA 200 ppm | 0.78w | 3.25s | 5.24n | 6.74kl | 7.67h-j | 8.57d-g | 8.89d-f | 5.88C |
| CMC 1% | 0.78w | 1.69v | 3.44rs | 4.38o-q | 5.08no | 6.03lm | 6.19lm | 3.94F |
| CMC 2% | 0.78w | 1.48vw | 2.88st | 3.49rs | 4.02qr | 4.25pq | 4.86n-p | 3.11G |
| Control | 0.78w | 4.11qr | 6.31lm | 7.78h-j | 9.11c-e | 10.04ab | 10.73a | 6.98A |
| Mean | 0.78G | 2.70F | 4.62E | 5.97D | 6.81C | 7.59B | 8.05A | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose

Concerning the effect of postharvest treatments, data showed that all treatments had significantly lower a* values as compared with untreated control of fresh-cut eggplant during storage in the two seasons. Fresh-cut eggplant coated with CMC at 1% or 2% were the most effective treatments in controlling the discoloration of the tissues of ready to use fresh-cut eggplant (lowest a* value) with significant differences between them in the two seasons during storage followed by chitosan at 2%, while untreated control had higher a* value during storage, which showed more darker and brownish in the two seasons. The other treatments were less effective in this concern. These results were true in the two seasons and in agreement with Helaly *et al.* [34] for GA

Table 5: Effect of inhibitors browning and storage periods on Chroma value of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| | Storage periods (days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
| | | | | 2016 | | | | |
| Chitosan 1% | 26.21a | 25.63a-e | 24.92a-g | 23.86a-k | 22.60e-p | 21.66h-q | 20.95k-r | 23.69AB |
| Chitosan 2% | 26.21a | 25.76a-d | 24.98a-f | 24.05a-j | 22.97c-n | 22.43f-p | 21.20j-q | 23.94AB |
| GA 100 ppm | 26.21a | 25.03a-f | 23.99a-k | 22.87c-o | 20.64i-r | 20.44m-r | 18.81qr | 22.57CD |
| GA 200 ppm | 26.21a | 25.57a-e | 24.72a-h | 23.47a-m | 22.40f-p | 21.39i-q | 19.84o-r | 23.37BC |
| CMC 1% | 26.21a | 25.87a-c | 25.21a-f | 24.2a-j | 23.01b-n | 22.69d-p | 21.87g-q | 24.16AB |
| CMC 2% | 26.21a | 26.08ab | 25.65a-e | 24.45a-i | 23.70a-l | 22.94c-n | 22.65e-p | 24.53A |
| Control | 26.21a | 24.90a-g | 23.26a-n | 21.87g-q | 20.37m-r | 19.72p-r | 18.00r | 22.05D |
| Mean | 26.21A | 25.55A | 24.68B | 23.55C | 22.24D | 21.61D | 20.48E | |
| | | | | 2017 | | | | |
| Chitosan 1% | 24.37a | 23.10a-f | 22.55a-h | 21.59a-j | 20.60b-m | 19.62f-m | 18.80i-o | 21.51B |
| Chitosan 2% | 24.37a | 23.40a-d | 22.68a-g | 22.12a-i | 20.86a-l | 20.12c-m | 19.36g-m | 21.84A-C |
| GA 100 ppm | 24.37a | 21.76a-i | 21.18a-k | 20.05d-m | 18.06j-o | 17.70k-o | 15.62n-o | 19.82D |
| GA 200 ppm | 24.37a | 23.06a-f | 22.13a-i | 21.37a-j | 20.06c-m | 18.88h-n | 17.55l-o | 21.06C |
| CMC 1% | 24.37a | 23.63a-c | 22.99a-f | 22.36a-h | 21.39a-j | 20.19b-m | 19.98d-m | 22.12AB |
| CMC 2% | 24.37a | 23.76ab | 23.37a-e | 22.66a-g | 21.91a-i | 20.94a-l | 20.71b-l | 22.53A |
| Control | 24.37a | 21.38a-j | 20.72b-l | 19.80e-m | 15.55l-o | 17.00m-o | 15.18o | 19.14D |
| Mean | 24.37A | 22.87B | 22.23BC | 21.42C | 19.77D | 19.21D | 18.16E | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose

and chitosan, Ali *et al*. [20] on chitosan, found that browning in fresh-cut eggplant was observed in untreated control represented a rapid increment in a* value. Also, found that chitosan treatment have a preventive effect against any changes that might occur in color indicating a lowest (a* value). Also, Ghidelli *et al.* [6], who work on eggplant and found the association between a lower L value and a higher a* value and the increase in tissue browning.

**Color (Chroma Values):** As shown in Table (5) showed that the Chroma values (C ) values of fresh-cut eggplant gradually decreased as the storage period extended. These results were true in the two seasons and in agreement with Helaly *et al.* [34].

Concerning the effect of postharvest treatments, data showed that all treatments had significantly higher C values as compared with untreated control except GA at 100 ppm treatment of fresh-cut eggplant during storage in the two seasons. Fresh-cut eggplant coated with CMC at 1% or 2% and chitosan at 2% were the most effective treatments in reducing the loss of C values, resulted higher value of C with no significant differences between them in the two seasons during storage. The other treatments were less effective in this concern, while fresh-cut eggplant treated with distilled water (control) or GA at 100 ppm had low C value during storage with no significant differences between them in the two seasons. These results were true in the two seasons and in agreement with Helaly *et al.* [34] for GA and chitosan.

Ali *et al*. [20] concluded that chitosan (2%) and CMC (2%) were the most effective treatments for inhibiting enzymes, obtaining good color and lowering non enzymatic browning in fresh eggplant rings during storage.

These inhibitory effects of coated chitosan treatment on enzymatic browning were related with the prevention of PPO enzyme activity. Browning is mostly the result of the activity of PPO enzyme acting on phenolic compounds to produce dark colored polymers when sugarcane is crushed to release the juice [45].

The significantly less overall color changes observed in chitosan treatment was highly due to the gas barrier properties of fruits, resulting in less metabolic or other biochemical processes that could have caused undesirable color changes for fresh-cut apples [46].

Gibberellic acid maintaining postharvest quality by delaying the loss of chlorophyll and consequently retarded the appearance of brown color [44].

Table 6: Effect of inhibitors browning and storage periods on fruit firmness (kg/cm$^2$) of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| | Storage periods (days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
| | | | | 2016 | | | | |
| Chitosan 1% | 5.90a | 5.63a-f | 5.20a-l | 4.80d-n | 4.70h-n | 4.30k-q | 3.50p-s | 4.86C |
| Chitosan 2% | 5.90a | 5.70a-e | 5.27a-j | 5.17a-k | 4.70f-n | 4.40j-q | 3.97m-r | 5.01AB |
| GA 100 ppm | 5.90a | 5.53a-h | 4.60e-n | 4.40h-o | 4.30i-p | 3.60n-r | 3.20rs | 4.50E |
| GA 200 ppm | 5.90a | 5.60a-g | 4.83c-n | 4.73e-n | 4.57h-o | 4.03l-r | 3.47q-s | 4.73D |
| CMC 1% | 5.90a | 5.77a-c | 5.53a-h | 5.43a-i | 4.77d-n | 4.60h-n | 4.30j-q | 5.19AB |
| CMC 2% | 5.90a | 5.87ab | 5.83ab | 5.73a-d | 4.90b-m | 4.80c-n | 4.63g-n | 5.38A |
| Control | 5.90a | 5.40a-i | 4.40j-q | 4.20k-q | 4.17l-r | 3.60o-s | 2.77s | 4.34E |
| Mean | 5.90A | 5.64A | 5.09B | 4.92B | 4.58C | 4.19D | 3.69E | |
| | | | | 2017 | | | | |
| Chitosan 1% | 5.37a | 5.07a-d | 4.37a-k | 4.00d-l | 3.80e-m | 3.63f-n | 2.73m-p | 4.14BC |
| Chitosan 2% | 5.37a | 5.20a-c | 4.47a-i | 4.30a-k | 4.23a-l | 4.00d-l | 3.23k-p | 4.40AB |
| GA 100 ppm | 5.37a | 4.67a-f | 4.03d-l | 3.63e-m | 3.37h-o | 3.30j-p | 2.43op | 3.82D |
| GA 200 ppm | 5.37a | 4.80a-e | 4.13c-l | 3.93d-l | 3.53g-o | 3.43i-o | 2.57n-p | 3.97C |
| CMC 1% | 5.37a | 5.27a-c | 4.53a-i | 4.40a-j | 4.37a-k | 4.20b-l | 3.43i-o | 4.51A |
| CMC 2% | 5.37a | 5.33ab | 3.70a-f | 4.60a-h | 4.53a-i | 4.47a-i | 3.80e-m | 4.69A |
| Control | 5.37a | 4.67a-g | 3.83e-m | 3.70e-n | 3.27j-p | 3.13l-p | 2.23p | 3.74D |
| Mean | 5.37A | 5.00B | 4.30C | 4.08CD | 3.87DE | 3.74E | 2.92F | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose

**Firmness:** Data in Table (6) show that firmness of fresh-cut eggplant was decreased continuously with the prolongation of storage period. These results were in agreement with those obtained by Miran and Javanmard [18] on fresh-cut eggplant. Losing firmness is the significant change during storage of fruits and vegetables and depends upon the metabolic changes and water.

Concerning the effect of postharvest treatments, data revealed that various applied treatments gave significantly greater firmness of fresh-cut eggplant than untreated control except for GA at 100 ppm during storage in the two seasons. Fresh-cut eggplant dipped in solution of carboxy methyl cellulose at 1% or 2% and chitosan at 2% were the most effective treatments in reducing the loss of firmness during storage with no significant differences between them in the two seasons, followed by chitosan at 1% treatment. However, GA at 200 ppm treatment was less effective in this concern. The lowest value of fresh-cut eggplant firmness was obtained from untreated control and GA at 100 ppm treatment with no significant differences between them in the two seasons. These results were in agreement with Miran and Javanmard [18] for carboxy methyl cellulose and Raymond *et al.* [47] for chitosan.

The faster reduction in firmness in untreated fruits might also be due to the normally occurring ripening process during storage periods which mainly occurs by degradation of the middle lamella of the cell wall [48].

The beneficial effect of methylcellulose coating on firmness during storage probably due to coating reduces the metabolism and keeping up the storage life [49]. Also, CMC coating retarded degradation of insoluble proto-pectins to the more soluble pectic acid and pectin.

The favorable effect of chitosan on the maintaining firmness of fruits could be due to fruits treated with chitosan had significantly the lower in malondialdehyde contents and relative leakage rates, as an indicator of membrane integrity than untreated control fruit and indicating maintained higher membrane integrity. Also, could be due to their higher antifungal activity and be covering of the cuticle and Lenticel, thereby reducing infection, respiration and other ripening processes during storage and preserving the maintenance of membrane integrity [50].

In general, the interaction between postharvest treatments and storage periods, data revealed that fresh-cut eggplant dipped in carboxy methyl cellulose 2% and 1% or chitosan at 2% was the most obvious in maintaining fresh-cut eggplant firmness during all storage periods with no significant differences between them in the two seasons.

**Polyphenol Oxidase Activity (PPO):** Data in Table (7) indicate that PPO activity of fresh-cut eggplant increased with the prolongation of storage period in the two seasons. These results are in agreement with those

Table 7: Effect of inhibitors browning and storage periods on Polyphenol oxidase activity (mg/ 100 g F.W) of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| Treatments | Storage periods (per days) 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | | 2016 | | | | |
| Chitosan 1% | 69.23s | 76.93l-s | 79.30k-q | 80.93j-p | 82.53i-n | 83.13h-n | 85.37h-m | 79.63D |
| Chitosan 2% | 69.23s | 75.90n-s | 76.80m-s | 79.03k-r | 80.73j-p | 81.37j-o | 83.47h-n | 78.08D |
| GA 100 ppm | 69.23s | 85.53g-l | 86.83g-k | 90.30f-i | 95.53ef | 96.57ef | 108.17cd | 90.31B |
| GA 200 ppm | 69.23s | 82.37i-n | 84.07h-n | 85.93g-k | 88.40f-j | 91.63f-h | 94.10e-g | 85.10C |
| CMC 1% | 69.23s | 70.60rs | 71.93q-s | 73.27o-s | 73.63o-s | 75.67n-s | 76.27n-s | 72.94E |
| CMC 2% | 69.23s | 69.47s | 69.87s | 69.90s | 71.47q-s | 71.70q-s | 72.73p-s | 70.62E |
| Control | 69.23s | 96.27ef | 101.77de | 107.33cd | 112.13c | 123.57b | 137.33a | 106.80A |
| Mean | 69.23F | 79.58E | 81.51DE | 83.81D | 86.35C | 89.09B | 93.92A | |
| | | | | 2017 | | | | |
| Chitosan 1% | 70.57s | 77.77n-q | 80.50m-p | 82.47k-n | 83.83j-m | 84.73i-m | 86.53i-l | 80.91D |
| Chitosan 2% | 70.57s | 76.87p-r | 77.92n-q | 80.33m-p | 81.70l-p | 82.13k-o | 84.63i-m | 79.17E |
| GA 100 ppm | 70.57s | 86.73i-l | 88.57g-j | 91.93f-h | 96.70ef | 97.47de | 109.40c | 91.62B |
| GA 200 ppm | 70.57s | 83.70j-m | 85.47i-m | 87.23h-k | 89.63g-i | 93.23e-g | 95.30ef | 86.45C |
| CMC 1% | 70.57s | 71.47s | 73.03q-s | 74.07q-s | 74.80q-s | 76.67p-r | 77.03o-r | 73.95F |
| CMC 2% | 70.57s | 70.77s | 70.93s | 71.47s | 72.43rs | 72.80q-s | 73.50q-s | 71.78G |
| Control | 70.57s | 97.13e | 102.60d | 108.57c | 113.20c | 125.40b | 138.40a | 107.98A |
| Mean | 70.57G | 80.63F | 82.72E | 85.15D | 87.47C | 90.35B | 94.97A | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose

obtained by Miran and Javanmard [18] on fresh-cut eggplant suggested that PPO enzyme activity increase when eggplant fruits are cut and that the activity of phenolase was closely associated with the development of browning.

The increase of PPO activity in control treatment after cutting is mainly due to activation process from latent to fully active form. In fact, as previously reported by Cantos *et al.* [51] tissue wounding involves the decompart metallization of cellular components with the subsequent release of proteases involving a cascade of reactions leading to the activation of latent PPO.

Concerning the effect of postharvest treatments, data revealed that all treatments reduced the activity of PPO during storage as compared with untreated control of fresh-cut eggplant during storage in the two seasons. Fresh-cut eggplant dipped in solution of carboxy methyl cellulose at 1% and 2% were the most effective treatments in delaying PPO activity during storage with no significant differences between them in the first season followed by chitosan at 1% or 2% with no significant differences between them in the first season. However, GA at 100 ppm treatment was less effective in this concern, while, untreated control had the higher increased in the activity of PPO enzyme in the two seasons. These results were in agreement with Miran and Javanmard [18] for carboxy methyl cellulose and Helaly *et al.* [34] for GA and chitosan and may be due to these materials reduced respiration rate and which provides a decrease in metabolic activities and suppressing the enzyme activities during storage.

The inhibitory effect of chitosan treatment on PPO activity is probably due to a low $O_2$ availability in the sweet cherry fruit [46]. The reduction in skin and flesh color changes is due to the preservation of cell compartmentalization and separation of PPO and POD enzymes from their phenolic substrates. Similarly inhibited POD and PPO activities have been observed in response to alternative technologies to chitosan coating employed on different fruit to improve their postharvest life [52].

Gibberellic acid decreased the enzyme activity of polyphenol oxidase by GA treatment is due to the depression in moisture loss, respiration rate and conversion of insoluble solids to simpler forms [40, 53].

In general, the interaction between postharvest treatments and storage periods, data revealed that fresh-cut eggplant dipped in carboxy methyl cellulose 2% or 1% were reduced PPO activity with no significant differences between them compared with the other treatments or untreated control after 12 days of storage in the two seasons.

Table 8: Effect of inhibitors browning and storage periods on total phenols (mg/ 100 g F.W) of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| Treatments | Storage periods (per days) 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | | 2016 | | | | |
| Chitosan 1% | 35.51a | 32.87cd | 30.55f-h | 24.78n-p | 22.64rs | 19.52uv | 16.39w | 26.04D |
| Chitosan 2% | 35.51a | 33.55bc | 31.89d-f | 27.08kl | 24.62op | 21.59st | 19.55uv | 27.68C |
| GA100 ppm | 35.51a | 31.14e-g | 26.07l-n | 22.12s | 18.27v | 14.14yz | 11.54a | 22.69F |
| GA200 ppm | 35.51a | 32.23c-e | 28.10jk | 23.62p-r | 21.84s | 18.60v | 14.68xy | 24.94E |
| CMC 1% | 35.51a | 34.85ab | 32.49c-e | 29.33h-j | 26.65lm | 24.08o-q | 22.99q-s | 29.42B |
| CMC 2% | 35.51a | 35.11a | 33.21cd | 31.24e-g | 29.04ij | 26.48lm | 24.95n-p | 30.79A |
| Control | 35.51a | 30.01g-i | 25.36m-o | 20.29tu | 16.03wx | 13.08z | 9.49b | 21.40G |
| Mean | 35.51A | 32.82B | 29.67C | 25.50D | 22.73E | 19.64F | 17.08G | |
| | | | | 2017 | | | | |
| Chitosan 1% | 33.39a | 30.98b-d | 28.36fg | 22.93l-n | 20.44pq | 17.49st | 14.62u | 24.03D |
| Chitosan 2% | 33.39a | 31.84a-c | 29.52d-f | 25.72ij | 22.59mn | 19.36qr | 17.34st | 25.68C |
| GA100 ppm | 33.39a | 29.27ef | 24.37j-l | 20.89o-q | 16.64t | 12.36v | 10.51wx | 21.06F |
| GA200 ppm | 33.39a | 30.51c-e | 26.61hi | 21.45n-p | 19.48qr | 16.63t | 12.60v | 22.95E |
| CMC 1% | 33.39a | 32.43ab | 30.53c-e | 27.52gh | 24.74jk | 22.48m-o | 20.78pq | 27.41B |
| CMC 2% | 33.39a | 32.82 | 31.03b-d | 29.25ef | 27.90f-h | 24.09j-m | 22.67mn | 28.73A |
| Control | 33.39a | 28.05f-h | 23.58k-m | 18.58rs | 15.92tu | 11.94vw | 8.91x | 20.05G |
| Mean | 33.39A | 30.84B | 27.72C | 23.76D | 21.10E | 17.76F | 15.35G | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose

**Total Phenolic Content:** Data in Table (8) indicate that total phenolic content of fresh-cut eggplant decreased significantly with the prolongation of storage period in the two seasons. These results are in agreement with those obtained by Mohamed *et al*. [33] and Miran and Javanmard [18] on fresh-cut eggplant. The decrease in phenolic content on fresh-cut eggplant is probably due to the oxidation of PPO enzyme to give the colored quinones and quercetin was oxidized directly by PPO [54]. Moreover, Robards *et al*. [55] found that phenolic compounds have significant role oxidation processes as antioxidants and as substrates in browning reactions. During storage, the enzymatic oxidation is continued and the resulted quinones are polymerized non-enzymatically to give darker pigments, which explain the parallel consumption of phenols with the development of blackness throughout the storage period.

Concerning the effect of postharvest treatments, data revealed that fresh-cut eggplant dipped in solution of carboxy methyl cellulose at 1% and 2% were the most effective treatments in reducing phenolic compounds loss during storage with significant differences between them, followed by chitosan at 2% treatment in the two seasons. The lowest values of phenolic compounds were obtained from untreated control in the two seasons. These results were in agreement with Miran and Javanmard [18] for carboxy methyl cellulose and Jongsri *et al.* [13] for chitosan and may be due to these materials reduced respiration rate and which provides a decrease in metabolic activities and suppressing the enzyme activities during storage.

The main function of chitosan or CMC is strengthened the cell wall and stabilizing the cell membrane [30], thus keeps PPO, which is membrane bound enzyme, away from its phenolic substrates present mainly in vacuoles leading to preserving phenolic content and inhibiting browning process [54].

Chitosan has been reported to increase the potential of the reactive oxygen species scavengers, leading to increased contents of phenolic compounds and antioxidants [16]. Also, treatment with different concentrations of chitosan has also been reported to activate the antioxidant enzymes catalase (CAT), superoxide dismutase (SOD) and peroxidase (POD), which are an important part of the antioxidant potential during storage, in tomato and guava [17, 50].

Regarding the interaction between postharvest treatments and storage periods, data revealed that fresh-cut eggplant dipped in carboxy methyl cellulose 2% or 1% and chitosan at 2% were the most effective treatment in maintaining the phenolic content with no significant differences between them in the second seasons compared with the other treatments or untreated control after 12 days of storage in the two seasons.

Table 9: Effect of inhibitors browning and storage periods on total microbial count (cfu $X^{-1}g$) of fresh-cut eggplant during cold storage at 5°C in 2016 and 2017 seasons

| | Storage periods (per days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | 0 | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
| | | | | 2016 | | | | |
| Chitosan 1% | 0.00p | 1.67m-p | 2.00l-o | 2.67j-o | 3.67g-l | 4.33e-j | 5.33c-g | 2.81D |
| Chitosan 2% | 0.00p | 1.00op | 1.33n-p | 1.67m-p | 2.67j-o | 3.33h-m | 4.00f-k | 2.00E |
| GA 100 ppm | 0.00p | 2.67j-o | 3.33h-m | 4.67d-i | 5.33c-g | 5.67b-f | 6.67a-c | 4.05B |
| GA 200 ppm | 0.00p | 2.33k-o | 3.00i-n | 4.00f-k | 4.67d-i | 5.33c-g | 6.00b-e | 3.62BC |
| CMC 1% | 0.00p | 2.67j-o | 3.00i-n | 3.67g-l | 4.33e-j | 5.00c-h | 6.33b-d | 3.57C |
| CMC 2% | 0.00p | 2.00l-o | 2.67j-o | 3.00i-n | 3.33h-m | 4.33e-j | 5.67b-f | 3.00D |
| Control | 0.00p | 3.33h-m | 4.67d-i | 5.33c-g | 6.33b-d | 7.33ab | 8.33a | 7.05A |
| Mean | 0.00G | 2.24F | 2.86E | 3.57D | 4.33C | 5.05B | 6.05A | |
| | | | | 2017 | | | | |
| Chitosan 1% | 0.00q | 2.00n-p | 2.67l-p | 3.67i-n | 4.67f-k | 5.00e-j | 6.33b-f | 3.48E |
| Chitosan 2% | 0.00q | 1.33pq | 1.67o-q | 2.33m-p | 3.33j-o | 4.00h-m | 5.00e-j | 2.52F |
| GA 100 ppm | 0.00q | 3.67i-n | 4.67f-k | 5.33d-i | 5.67d-h | 6.67b-e | 7.67a-c | 4.81B |
| GA 200 ppm | 0.00q | 3.33j-o | 4.67f-k | 4.67f-k | 5.67d-h | 6.33b-f | 7.67a-c | 4.62BC |
| CMC 1% | 0.00q | 3.00k-p | 4.00h-m | 4.33g-l | 5.00e-j | 6.00c-g | 7.00b-d | 4.19CD |
| CMC 2% | 0.00q | 2.67l-p | 3.67i-n | 4.00h-m | 5.00e-j | 5.67d-h | 6.67b-e | 3.95DE |
| Control | 0.00q | 4.00h-m | 5.67d-h | 6.67b-e | 7.00b-d | 8.00ab | 9.00a | 5.76A |
| Mean | 0.00G | 2.86F | 3.86E | 4.43D | 5.19C | 5.95B | 7.05A | |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range tests. GA = Gibberellic acid. CMC = Carboxy methyl cellulose

**Total Microbial Count:** Data in Table (9) indicate that microbial growth in fresh-cut eggplant increased significantly with increasing the storage period particularly in untreated control. These results were true in the two seasons. Similar results were reported by Mohamed *et al*. [33] and Miran and Javanmard [18] on fresh-cut eggplant.

Concerning the effect of postharvest treatments, data revealed that there were significant differences in microorganism growth between all postharvest treatments and control. The fresh-cut eggplant treated with all used treatments had lower levels of microbial load in comparison to control treatment. Fresh-cut eggplant dipped in solution of chitosan at 2% provided the lowest count in all types of microorganisms followed by chitosan at 1% and carboxy methyl cellulose at 2% with no significant differences between them in the two seasons, while the other treatments showed less effective in reducing microbial growth. Untreated control had higher levels of microbial load. These results were true in the two seasons and agree with Miran and Javanmard [18] for carboxy methyl cellulose and Chong *et al.* [56] for chitosan.

The antimicrobial of chitosan is probably caused by the interaction between chitosan and the microbial cell membranes, which leads to the leakage of proteinaceous and other intracellular constituents. Chitosan can also penetrate to the nuclei of fungi and interferes with RNA and protein synthesis [57]. Also, this was probably due to the fungicidal action of chitosan that caused alteration in the function of the cellular membrane [58].

Chitosan has ability to resist several fungi and induce defense enzymes such as chitinase and chitosanase, which are associated with induced systemic resistance of fruits [59].

Concerning the interaction between postharvest treatments and storage periods, data revealed that fresh-cut eggplant dipped in chitosan 2% was the most effective treatments in reducing the levels of microbial load followed by chitosan 1% or carboxy methyl cellulose 2% and 1% with no significant differences between them compared with the other treatments, while untreated control had the highest value of microbial count after 12 days of storage at 5°C in the two seasons.

## CONCLUSIONS

Fresh-cut eggplant dipped in carboxy methyl cellulose at 2% was the most effective treatment in reducing weight loss percentage, color change of cut surface, polyphenol oxidase activity, total microbial count and maintained quality attributes (firmness and total phenols) and gave good appearance after 12 days of storage at 5°C.

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