Improving postharvest storage of fresh artichoke bottoms by an edible coating of *Cordia myxa* gum

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Abstract

This study aimed to prolong the shelf life of fresh-cut artichoke (*Cynara scolymus* L.) bottoms under refrigerated conditions (2 °C and 95 % RH) for a period of 9 d. Fresh artichoke bottoms were subjected to an edible coating of *Cordia myxa* gum (Cg) supplemented with or without calcium dichloride ($CaCl_2$) 1 %, or ascorbic acid (AsA) 1 %. The key postharvest quality parameters which were investigated were weight loss, browning, polyphenol oxidase activity (PPO), firmness, vitamin C, and total phenolic compounds (TPC). Moreover, the microbial load of artichoke bottoms during the storage was also measured which comprised of total aerobic mesophilic and psychrotrophic bacteria, fungi, and *E. coli*.

Results indicated that edible coating with Cg, when supplemented with $CaCl_2$ or AsA, had a significant positive effect on weight loss, vitamin C, and TPC. Browning and PPO activities were significantly inhibited by Cg supplemented with AsA. The mesophilic and psychrotrophic bacterial count was significantly reduced in the presence of $CaCl_2$ with or without Cg. For moulds and *E. coli* control, again Cg in combination with $CaCl_2$ seems to be the most effective treatment. Hence, based on these findings, it can be recommended that postharvest coating Cg supplemented with $CaCl_2$ could be a new application for delaying browning and extending the shelf-life of artichoke bottoms during refrigerated storage. Further research and development are required in commercial settings to test and scale the application of Cg in fresh-cut artichoke bottom industry.

***Keywords**:* Artichoke; edible coatings; shelf-life; ascorbic acid; calcium dichloride; *Cynara scolymus*

1. Introduction

The artichoke (*Cynara cardunculus* L.) is an important vegetable and medicinal plant species of the Mediterranean region. It is well known for its rich antioxidative, anticarcinogenic, antibacterial, and diuretic properties (de Facto et al., 2015; Garbetta et al., 2014). In recent years, minimal processing operations for artichoke such as removing outer leaves and core hairs are introduced to reduces transport and storage costs as well as preparation time in the consumers' kitchens (Ghidelli et al., 2013). However, fresh-cut artichokes deteriorate rapidly, primarily due to enzymatic browning, loss of moisture and firmness, microbial growth, and subsequent discolouration (Restuccia et al., 2014). One of the key enzymes responsible for browning and discolouration of the artichoke tissue is the Polyphenol oxidase enzyme (PPO) (Ghidelli et al., 2013). Various applications have been tested in the past to delay browning. For example, dipping in citric and ascorbic acid (Lattanzio et al., 1989), cysteine (Amodio et al., 2011; Cabezas-Serrano et al., 2013), calcium chloride, cyclodextrin, hexametaphosphate, and 4-hexylresorcinol (Ghidelli et al., 2013), coating with citric acid loaded sodium alginate (Del Nobile et al., 2009). More recently use of edible coating with soy protein isolate and bee-wax in combination with modified atmospheres (Ghidelli et al., 2015) has proved to be beneficial. However, the overall effect and use of these techniques are somewhat limited and not widely practised.

Edible coating of natural gums from plants like *Cordia myxa* alone or in combination with antioxidant supplements is a promising method for reducing enzymatic and oxidative deterioration and in turn increasing shelf-life of fresh-cut fruit and vegetables (Quezada-Gallo, 2009). *Cordia myxa* is a deciduous tree belonging to the *Boraginaceae* family. It is endemic to southeast Asia, growing naturally from Myanmar in the east to Afghanistan in West. Its half-ripe fruit is used as a vegetable, whereas ripe fruit is sweet and eaten raw (Haq et al., 2013). The mucilaginous extract of ripe fruit contains gum composed of an anionic polysaccharide which is covalently bound with protein (Benhura and Chidewe, 2011). *Cordia myxa* gum is well known for its emulsifying and binding properties. The gum has excellent adhesion, and cohesion properties hence can be easily prepared into a form of edible coating (Haq et al., 2015; Haq et al., 2016). Saha et al., (2017) reported how *Cordia myxa* gum has emerged as a novel edible coating and has been used in combination with

various natural antioxidants such as Vitamin E. The work on post-harvest application in fruit and vegetable of this gum is somewhat limited, some of the previous studies have tested the gum *Cordia* gum as a carrier of antioxidants to reduce oxidation in peanuts (Haq et al., 2015) and Chilgoza, *Pinus gerardiana* (Haq et al., 2013).

To our knowledge, this is the first study which focuses on the coating of artichoke bottoms with *Cordia myxa* fruit-based gum, as most of the previous work was done on fresh-cut artichoke head (Del Nobile et al. 2009; Ghidelli et al. 2015). The primary objective of this study was to investigate the effect of an edible coating of *Cordia myxa* fruit gum extract supplemented with ascorbic acid (AsA) or calcium dichloride ($CaCl_2$) on delaying the enzymatic browning and extending the shelf-life of artichoke bottoms during refrigerated storage for nine days.

2. Materials and Methods

2. 1. Preparation of Cordia myxa gum solution and coating formulations:

Ripe fruit of *Cordia myxa* was sourced from New Valley Governorate of Egypt. *Cordia myxa* fruit gum (Cg) extract from the ripe fruit was prepared according to the method prescribed by Haq et al. (2013). For preparation of 10 g L^{-1} gum cordial solution, 10 g of acid precipitated gum was added to 0.8 L of water, and the pH was adjusted to 7.0 using 0.1 mol L^{-1} NaOH between intermediate stages before glycerol was added at a rate of 0.2:1 g of acid precipitated gum, the solution was made up to 1 L with distilled water (Haq et al. 2013). For preparing of Cg coating solution containing either AsA powder 1% or $CaCl_2$ 1% (10 g L^{-1}), the steps described above for Cg cordial solution were followed, then AsA or $CaCl_2$ were slowly added into gum coating solutions. Afterwards, pH was measured using pH meter (EuTech Instruments, pH 510, Singapore), which finally reached to 5.4 and 7.2 pH, for AsA and $CaCl_2$ supplemented gum solutions, respectively.

2.2. Coating and storage of artichoke bottoms

Globe artichokes of variety *Imperial Star* were harvested from a private farm in El Beheira Governorate, Egypt. Once harvested, the fresh artichokes were cooled at 5 °C and 95 % RH for 24 h. To prepare the artichoke bottoms, outer green leaves were removed to obtain inner tender leaves, which were again cut-off by the sharp knife. A sharp knife cut the heads stems and all base of leaves were removed around the bottoms. Finally, the inner hairy chokes were removed to obtain

artichoke bottoms. Immediately, the bottoms were dipped in six different treatment solutions (table 1) for 5 min. Three bottoms were treated for every replicate and each treatment was done in triplicates. Hence there were nine samples per treatment, at every measure point (0,3,6,9 d), from which five bottoms were used for measuring firmness and browning index. Remaining four were used for chemical compounds and microbial load analysis. Besides, nine bottoms for each treatment were prepared for weight loss determination. Once the bottoms were removed from the coating solutions, they were placed in a sterile laminar flow hood at ambient conditions, for the coating to dry. After coating was dried, the samples were packed in polypropylene (PP) trays (thickness of PP trays was 403 µm, oxygen permeability of 179 ± 10 cc m^{-2} day atm, water vapour permeability of 0.55 g mm m^{-2} d^{-1} bar^{-1} at 25°C) and thermally sealed by the stretch film (thickness is 25 µm) and afterwards stored at 2 ºC and 95 % RH for 9 d for shelf life and chemical analysis.

Table 1. Coating solution types for different treatments of artichoke bottoms.

		Factor 1	
		Coating using *Cordia myxa* gum (Cg)	
		Without	With
Factor 2 Additives	None	●	●
	Ascorbic acid (AsA) solution (1%)	●	●
	$CaCl_2$ solution (1%)	●	●

2.3. Determination of weight loss, firmness, and browning index

Weight loss of artichoke bottoms was determined by weighing them immediately after air-drying and at 0, 3, 6 and 9 d. The results are shown as the percentage weight loss compared to the initial fresh weight.

To determine firmness, five bottoms from each treatment were used. Two points (in the ventral and dorsal surface) were tested for each artichoke bottoms. Firmness was measured using an FT011 penetrometer (Wagner Instruments, Italy), and values are presented as Newtons (N). Browning index (BI) was calculated according to Ruangchakpet and Sajjaanantakul (2007) by using equation 1.

$$BI = [100\ (x - 0.31)] / 0.17,\ where\ x = (a^* + 1.75L^*) / (5.645L^* + a^* - 0.3012b^*) \quad \ldots (1)$$

A Minolta colorimeter (Model CR-400 Chroma Meter, Konica Minolta, INC, Tokyo, Japan) was used for measuring a* and b* values. Each measurement was taken at three locations for each bottom. To calibrate the colorimeter, a standard white calibration plate was used.

2.4. Determination of vitamin C and total phenolic compounds

Vitamin C content of artichoke bottoms was determined using the titrimetric method with *2,6-dichlorophenol indophenol (Sigma- Aldrich)*, according to AOAC, 967.21 (2000) and expressed as g kg^{-1} on a fresh weight basis. Extraction of total phenolic compounds (TPC) from artichoke bottoms was done according to Murniece et al. (2014), 5 g of homogenised samples were extracted with ethanol (80/20 w/w) in a conical flask with a magnetic stirrer (magnet bar 3.0 cm × 0.5 cm) at 27 g for 1 h at room temperature (20 ± 1 °C). The extracts were filtered (paper No.1). The extraction process was done in triplicate. TPC was determined according to the Folin-Ciocalteu spectrophotometric method (Singleton et al. 1999). 0.5 ml of artichoke heads extract added to 2.5 ml of a 1/10 dilution of Folin-Ciocalteau reagent *(Sigma- Aldrich)* and, after 3 minutes 2 mL of sodium carbonate (Na_2CO_3) (75 g/L) was added. The sample was mixed and incubated for 30 minutes at room temperature, and then the absorbance was measured at 765 nm. Total phenols were expressed as gallic acid equivalents (GAE) g per kg on a fresh weight basis (g GAE kg^{-1}) of artichoke heads using a Gallic acid (97.5–102.2% (titration) Sigma Aldrich, China*)* standard curve.

2.5. Polyphenol oxidase activity

Polyphenol oxidase (PPO) activity was determined according to the method suggested by Cao et al. (2009), with some modifications. A total of 2.5 g of artichoke bottoms was homogenized in 5 mL of 200 mM sodium phosphate buffer (pH 6.5) containing 5 % (*w*/*w*) Polyvinylpolypyrrolidone (PVPP). After incubation on ice for 1 h, the homogenate was centrifuged at 5724 ×*g* for 10 min at 4 °C. The crude enzyme extract (100 µL) was subsequently incubated with 1.4 mL of 500 mM catechol in a final volume of 1.5 mL, and the increase in absorbance at 420 nm was monitored. The specific activity was expressed as µmol catechol s^{-1} kg^{-1}.

2.6. Microbiological analyses

Four artichokes bottoms were chopped in sterile conditions, and 25 g were aseptically weighed and homogenised in a stomacher (IUL, Barcelona, Spain) for 2 min with 0.25 L of 0.1 % sterile peptone water. Serial dilutions were made with the same diluent. The total aerobic mesophilic count was determined on plate count agar (PCA, Merck) following the pour plate method by incubation at 30 °C for 3 d (ICMSF, 1978)**.** The psychrotrophic bacterial count was determined on plate count agar

(PCA, Merck) following the pour plate method with an incubation temperature of 7 °C for 10 d (ICMSF, 1978)**.** Moulds were counted on Rose Bengal chloramphenicol agar base (RB, OXOID, CM0549) supplemented with chloramphenicol selective supplement (OXOID, SR0078) and incubated at 25 °C for 3 d (ICMSF, 1978).

The faecal coliforms were determined by the Most Probable Number (MPN) method, for a three-tube series using brilliant green bile lactose broth (BGBL, Difco) incubated at 44 °C for 2 d; if the gas formed, subcultures were made onto a Levine agar (Merck) and incubated at 37 °C for 2 d. The plates were then examined for *E. coli* colonies (ICMSF, 1978)**.** All the microbiological analyses were performed in triplicates. Microbial data were log-transferred (log CFU g^{-1}) before statistical analysis.

2.7. Statistical analysis

Data were analysed using R Version 3.6.0 (2019, Vienna, Austria). An ANCOVA (Analysis of Co-Variance) and Non-metric multidimensional scaling (MSD) model was used to test the influence of independent factor (various treatments) on response variables (quality parameters) for the storage time factor. MDS is particularly useful in this situation as unlike any other ordination methods, and it makes few assumptions about the nature of the data.

3. Results

3.1 Weight loss and firmness

Weight loss and firmness of artichoke bottoms were significantly affected by all the treatments and time factor (figure 1a, b) with p-values < 0.0001 and = 0.003, respectively. The effect was much stronger on weight loss rather than firmness. The lowest weight loss (2.53 %) was recorded for treatment Cg gum supplemented with ascorbic acid at the end of the storage period.

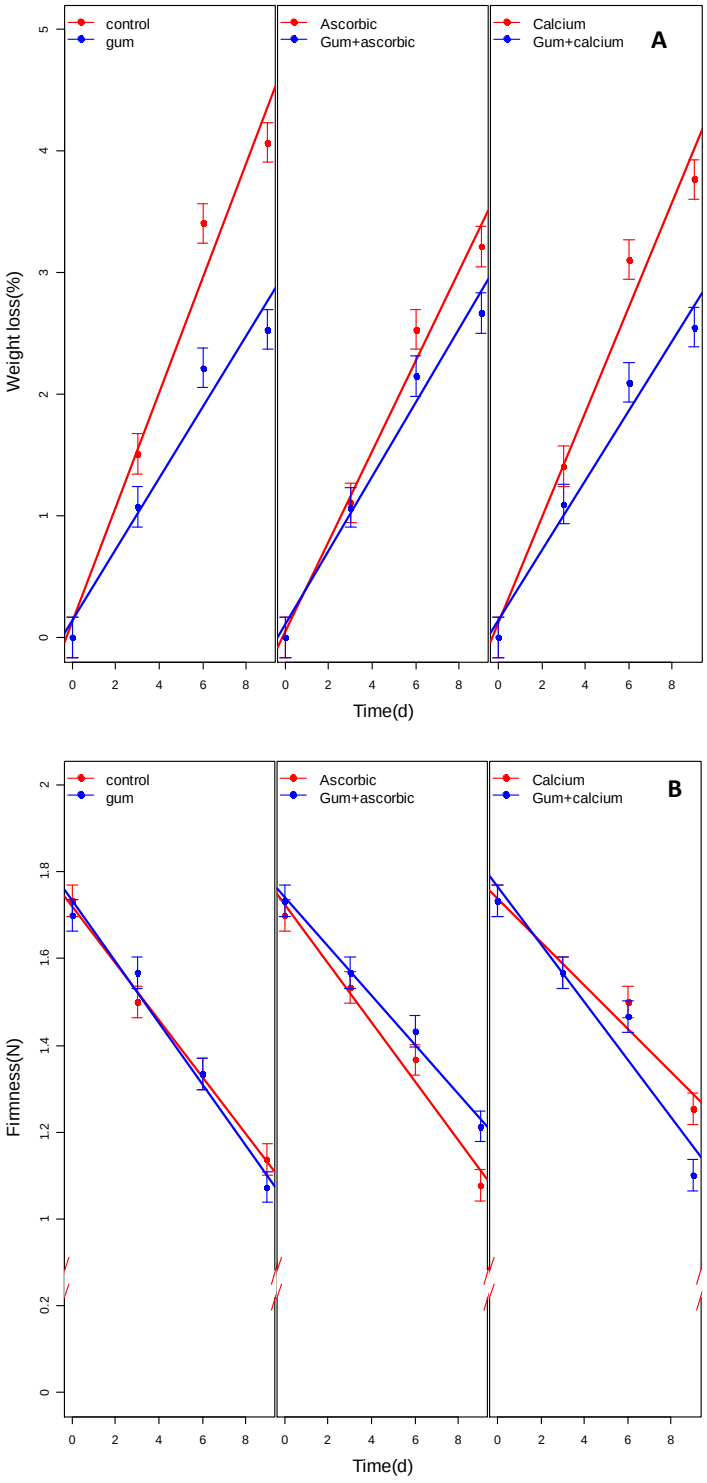


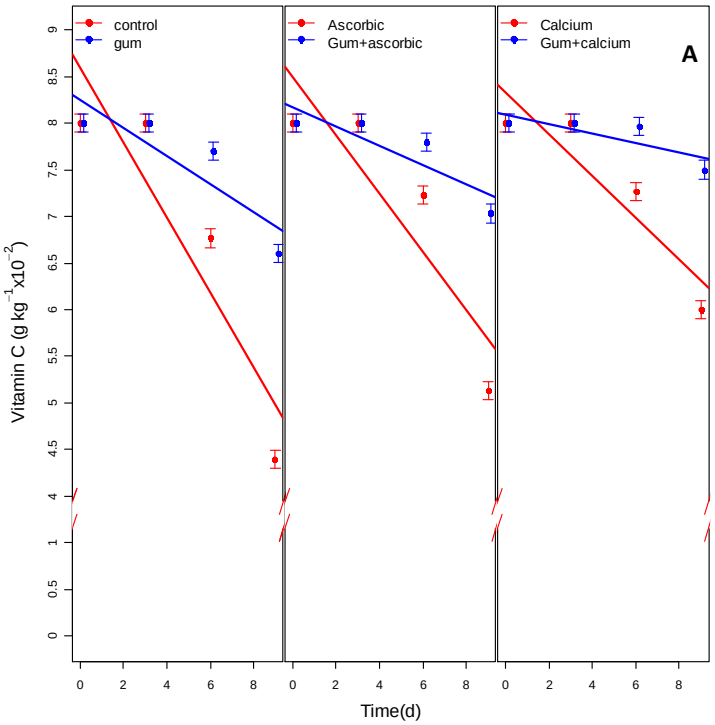
Figure 1: Effect of various treatments factors on weight loss (A) and firmness (B).
Note: Analysis of covariance for lines, 2-way ANOVA for points and standard error.

However, when time and treatment factors are combined to test the significance level, firmness seems to show no significance with p-value = 0.14. The most substantial decrease in weight loss

was observed in the presence of Cg, either with or without any supplements. At the end of the storage period, all Cg treatments (either alone or in combination with $CaCl_2$ or AsA) had significantly lower weight loss than control and other treatments. Hence the Cg factor is the most critical determinant of the artichoke bottom weight loss during refrigerated storage. Firmness was not affected by treatments until after 3 d of storage. At day 6 of storage, significantly ($P \leq 0.05$) higher firmness values were recorded from artichoke bottoms treated with $CaCl_2$ carried by Cg coating and AsA carried by Cg coating followed by treatment with Cg coating alone.

3.2 Vitamin C and Total Phenolic Content

Vitamin C and TPC contents of artichoke bottoms were significantly affected by the Cg treatment (figure 2a, b) with p-values < 0.0001. Cg coating resulted in a 34 % higher TPC content (with-Cg: 5.18 g Kg^{-1}; without-Cg: 3.41 g kg^{-1}) and an increased level of vitamin C, particularly at the end of the storage period. The most significant effect was observed when Cg was supplemented with $CaCl_2$, where final retention of the vitamin C and TPC after 9 d of storage was 0.07 and 4.96 g kg^{-1} from initial levels of 0.08 and 6.76 g kg^{-1} respectively.



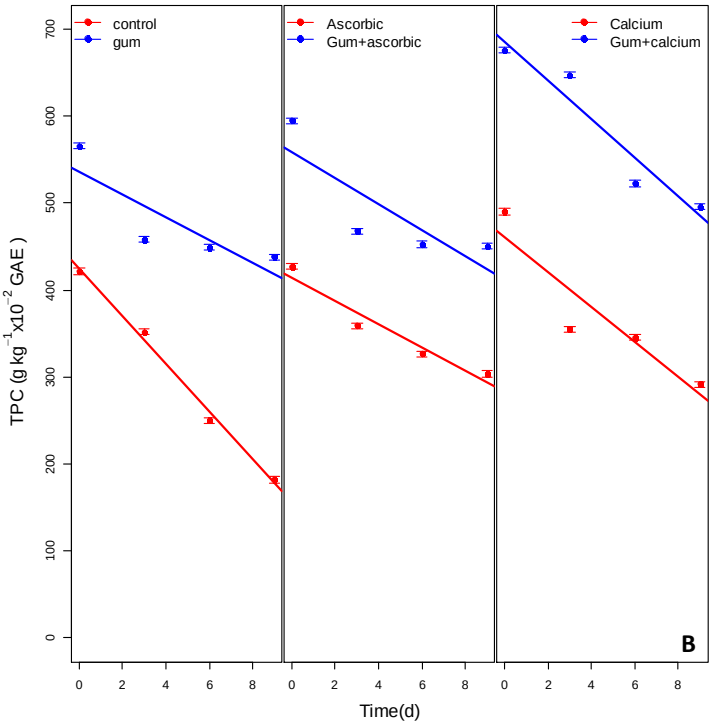


Figure 2: Effect of various treatments factors on vitamin C (A) and TPC (B). *Note: Analysis of covariance for lines, 2-way ANOVA for points and standard error.*

Vitamin C content of artichoke bottoms was not affected by any treatments at the beginning and up to 3 d of storage. However, Cg +$CaCl_2$, Cg+AsA, and Cg treatments showed significantly higher values of vitamin C content after 6 and 9 d of storage compared in comparison with control and treatments without Cg. The control treatment showed the lowest vitamin C content, but when compared with $CaCl_2$ and AsA treatments, the difference was not significant. During storage times, the best treatments for retaining TPC were $CaCl_2$ carried by Cg coating.

3.3 Browning index and PPO activity

Artichoke bottom tissue deterioration accelerated in the absence of Cg coating, as represented by the browning index and PPO activity as indicators of tissue decay. Browning index at the end of the storage period was significantly reduced in the presence of Cg factor with or without any supplements. With Cg browning index ranged around 40 – 45, whereas in the absence of gum coating increased these levels up to 60 (figure 3a). PPO activity was reduced significantly for all treatments ranging in between 4-5 µmol catechol s^{-1} kg^{-1} when compared to the control which was above 6 µmol s^{-1} kg^{-1} catechol at the end of the storage period.

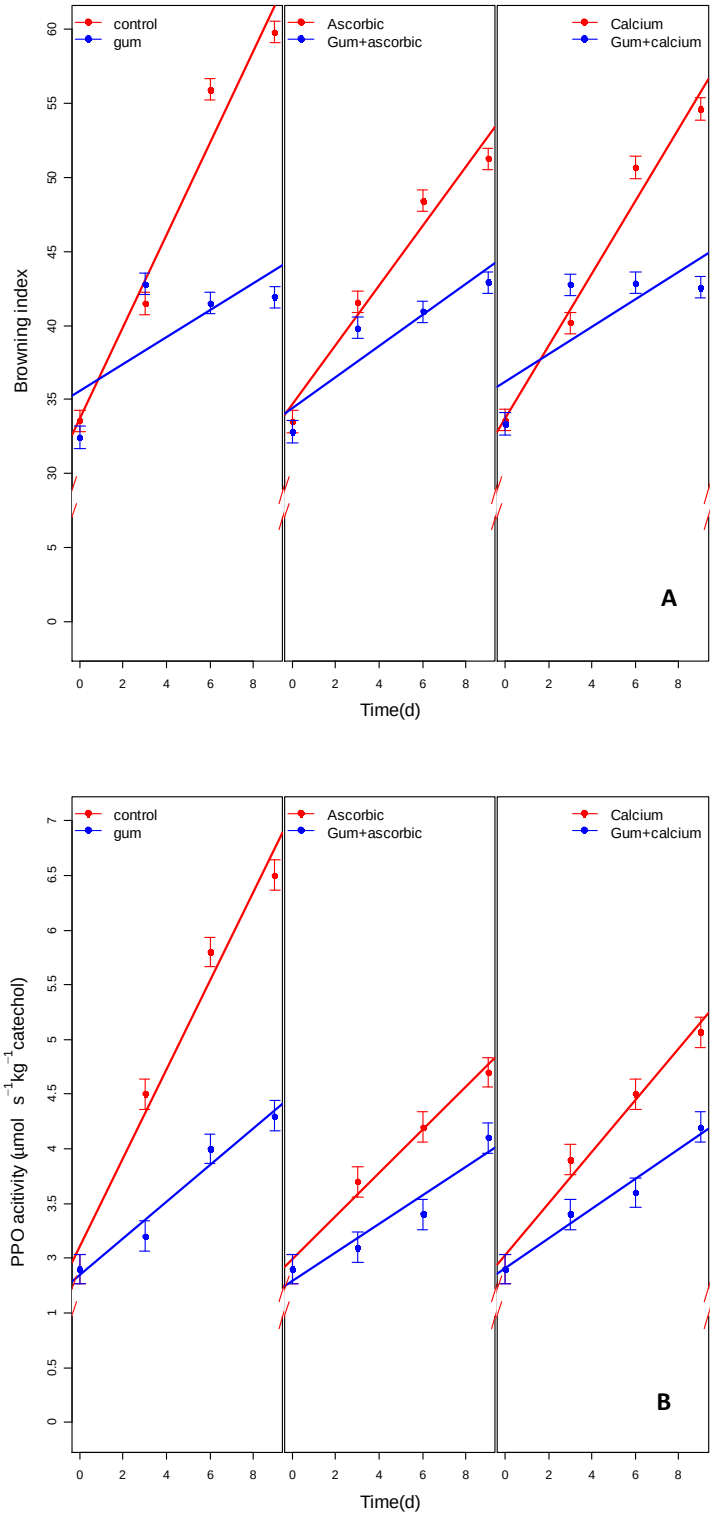
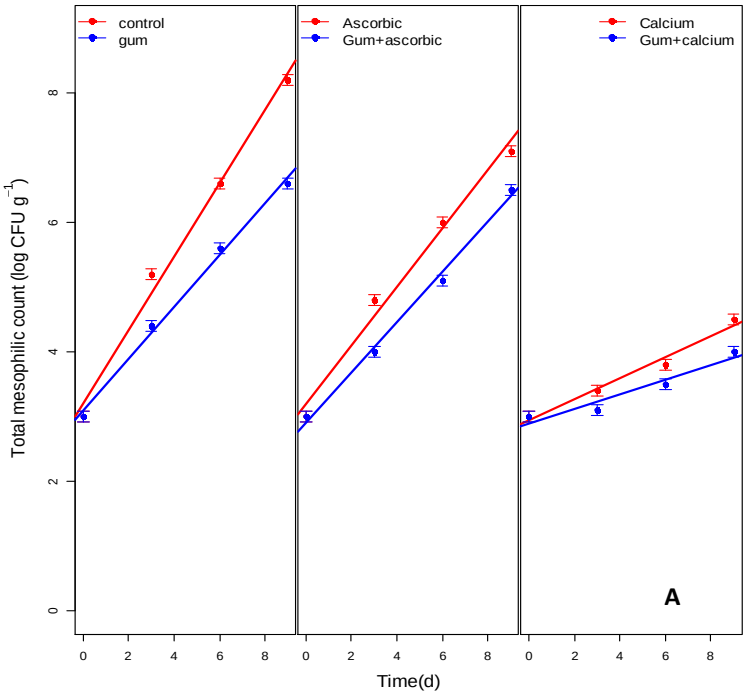


Figure 3: Effect of various treatments factors on browning (A) and PPO activity (B). *Note: Analysis of covariance for lines, 2-way ANOVA for points and standard error.*

After 3 d of storage, the lowest browning index was observed in the bottoms treated with Cg+$CaCl_2$, followed by Cg+AsA coating. Control treatment showed higher browning index compared with all treatments after 6 d of storage. Moreover, artichoke bottoms dipped in $CaCl_2$ solution did not show significant differences as compared to AsA treatment. The lowest browning index values after 6 and 9 d of storage were obtained from all Cg coating treatments without significant differences among them. As expected, PPO activity enhanced with increasing storage period and the highest PPO activity was recorded for the control treatment (figure 3b) after 6 and 9 d of storage. Edible coating with Cg gum loaded with $CaCl_2$ was the most effective treatment which suppressed PPO activity followed by Cg gum supplemented with AsA.

3.4 Mesophilic and psychrotrophic bacterial counts

The mesophilic and psychrotrophic bacterial count was significantly reduced in the presence of $CaCl_2$ either with or without Cg (figure 4). However, the presence of Cg in addition to $CaCl_2$ did help in the reduction of log CFU/g for both types of bacteria, particularly in the early days of storage (3 and 6 d).



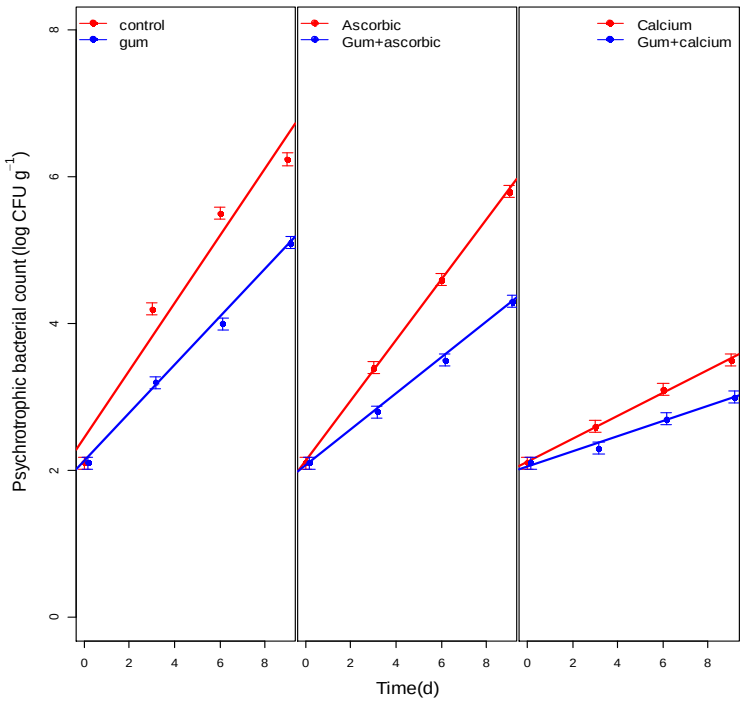


Figure 4: Effect of various treatments factors on aerobic mesophilic (A) and psychrotrophic bacterial count (B). *Note: Analysis of covariance for lines, 2-way ANOVA for points and standard error.*

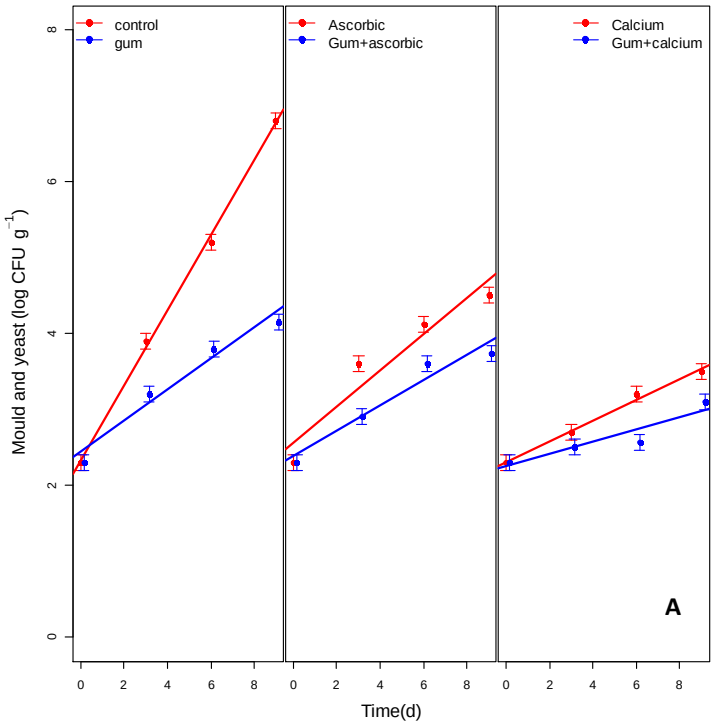
B

Throughout the storage period, the control treatment showed the highest levels of mesophilic bacteria on artichoke bottoms compared with all other treatments. The lowest mesophilic bacteria values were obtained for Cg+$CaCl_2$, followed by $CaCl_2$ treatment and Cg+AsA treatments. After 3 and 6 d of storage, total psychrotrophic bacteria significantly reduced by Cg+$CaCl_2$ treatment while all other treatments were statistically similar but lower than the control treatment. At the end of the storage period (9 d), statistical differences were observed among all treatments. At the end of the storage period lowest total psychrotrophic bacteria value was obtained from Cg+$CaCl_2$ coating followed by $CaCl_2$, Cg+AsA, AsA, Cg and control, subsequently (figure 4b).

3.5 Mould and E. coli

Coating artichoke bottoms with Cg+$CaCl_2$, $CaCl_2$, and Cg+AsA treatments proved to be the most effective treatments for reducing total mould and yeast count during the entire storage period (figure 5a, b). Moreover, Cg coating and AsA treatments significantly suppressed the growth of mould and yeast compared when compared with control treatment. Initial *E. coli* count for fresh artichoke was (~ 3 log CFU g^{-1}) not satisfactory as per the European Union Commission Regulation (EC) No.

2073/2005 criteria for read-to-eat fresh fruits and vegetables. However, in most cases artichoke bottoms will be cooked before eating, which lower down the risk. The reason for a high initial E. coli count is most likely due to the contamination at the field during growing and harvest season. In Egypt, the majority of the farmers use farmyard manure which can be contaminated by *E. coli*. During our experiment, the control treatment samples showed significantly higher values of *E. coli* when compared with all the treatments. Treatment with Cg + $CaCl_2$ significantly reduced the *E.coil* count followed by $CaCl_2$, Cg, and Cg + AsA treatments subsequently, without significant differences among them at the end of the storage period (9 d).



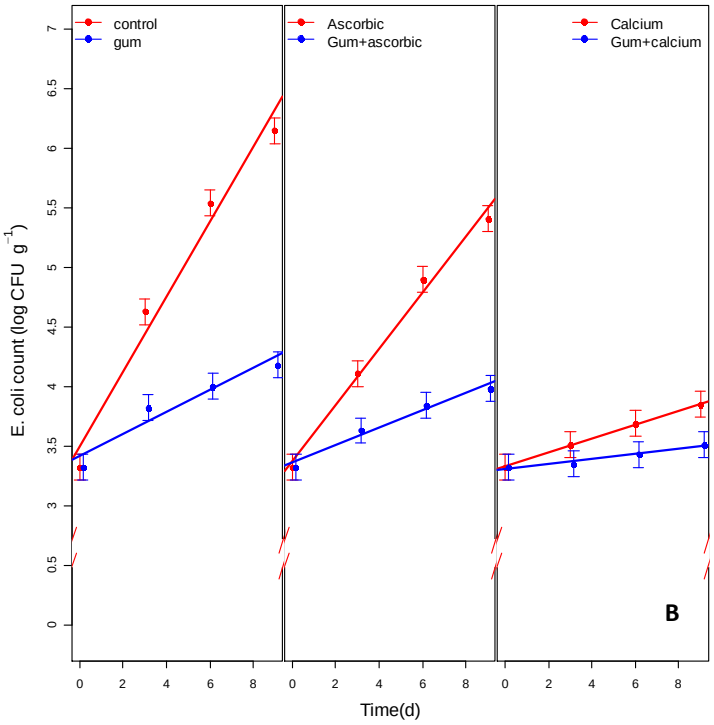


Figure 5: Effect of various treatments factors on moulds (A) and E-coli count (B). *Note: Analysis of covariance for lines, 2-way ANOVA for points and standard error.*

3.6 Non-metric multidimensional scaling

Nonmetric multidimensional scaling plot on all the response variables is presented in figure 6. Figure 6a represents the two indexes which the analysis has created, first is MDS1 (x-axis) which track the changes with time in storage and second MDS2 (y-axis) shows the impact of various treatments.

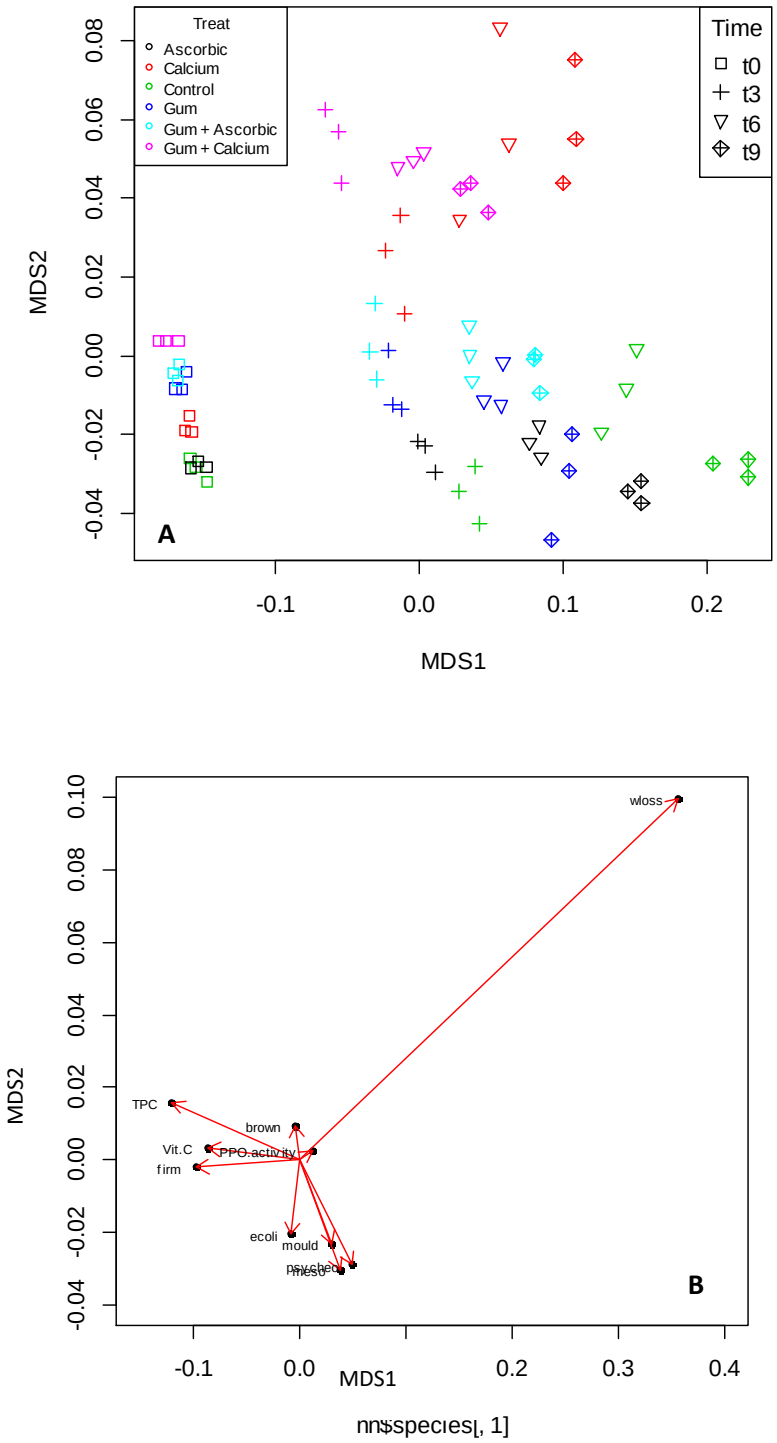


Figure 6: Nonmetric multidimensional scaling (MDS) of response variables.
Note: This is the multi-dimensional scaling plot. The axes are two indexes (MDS1, and MDS2) which the program has worked out from the grid of 10 output variates in the data. These axes are at right angles to each other, and each replicate is a data point (A).

The results of the MDS analysis shows that treatment with $CaCl_2$ and Cg+$CaCl_2$ has the maximum impact on the response variables. Figure 6b which is an arrow plot shows how each of the measured quality parameter inputs to the axes in the figure 6a, to some extent like weights for each parameter defined by the tip of the arrow. These weights are used to work out the score from data to understand which are the quality parameters which are affected most. Hence it is clear from the arrow plot that the parameters which are modified the most by were weight loss, TPC and browning index.

4. Discussion

Deterioration of plant tissue is a series of cascading events. The complexity of postharvest deterioration of fresh fruits and vegetables is displayed in the strong interactions between the different plant physiological and microbiological parameters. From a plant physiology perspective, minimally processing steps of artichoke including cutting and trimming induces some undesirable changes such as enzymatic browning and increased respiration rates (Ghidelli et al., 2013; Cefola et al., 2014). The most important finding of this study was that a Cg + $CaCl_2$ treatment could extend the shelf-life and preserve bioactive compounds of the artichoke bottoms. $CaCl_2$ is an inexpensive, edible and approved (US FDA, USA) chemical for postharvest use (Saftner et al., 1998). Notably, it is known that postharvest application of $CaCl_2$ showed no adverse effect on consumer acceptance of fruit (Saftner et al., 1999). Saftner et al. (1998) and Hernandez-Munoz et al., (2008) stated that enhancing the Ca content in or on the surface of plant tissue by postharvest treatment reduces disorders and maintains the quality during storage of various fruit, such as apple and strawberry. There are various other examples where the postharvest application of $CaCl_2$ treatments enhanced the nutritional quality of fruits (Ramezanian et al., 2010), and reduced the loss of nutraceutical compounds (Aghdama et al., 2013).

Edible coatings tend to reduce or control the moisture transfer between the food product and their surrounding environment, which have a controlling effect on metabolism and respiration rates. The role of coating for reducing weight loss (in the form of moisture loss) might be due to the modification of the internal atmosphere and reduced respiration rates (Debeaufort et al., 1998). Whereas, the role of $CaCl_2$ (figure 1b) for maintaining firmness might be due to the formation of

Ca-pectates which are known to enhance middle lamella and cell wall resistance to polygalacturonase activity (Poovaiah, 1986). The observed decrease in the vitamin C content of artichoke bottoms during refrigerated storage may be due to the oxidative deterioration of vitamin C (Restuccia et al., 2014). Our results agree with Helaly et al. (2016), who reported a gradual decreased in vitamin C content in fresh-cut artichoke coated with 1 % chitosan stored at 0 °C for 6 d. Higher retention of vitamin C in gum-based treatments and combinations with AsA, can be related to the antioxidant properties (Freire et al., 2005) of *Cordia myxa* and AsA. The artichoke bottoms treated with Ca carried by Cg coating, AsA carried by Cg coating, and Cg coating has higher TPC than in control for all sampling times. Ali et al. (2013) reported similar results for tomatoes, where coating played a significant role in preserving TCP.

There are previous examples of reduced enzymatic browning in minimally processed artichokes when treated with AsA (1 % w/v), and CaCl aqueous solution (Del Nobile et al., 2009; Gómez di Marco et al., 2012). Tapia et al. (2008) stated the use of AsA as an anti-browning agent for various fresh-cut fruits. Our results on AsA treatment and its anti-browning properties corroborated positively with these previous studies. The PPO activity increased in all samples during the storage period. However, it was significantly lower for all gum-based treatments. The most significant retardation in PPO activity was observed in Cg + AsA treatment, followed by Cg + $CaCl_2$. These results are following the results of Sun et al. (2010) who found that chitosan + AsA decreased PPO activity. It has been noticed that using AsA or any other antioxidants (reducing agents) can prevent the oxidation of phenolic compounds (Gil et al., 1998). Rico et al. (2007) suggested possible mechanisms of AsA as PPO activity retardant, which act as an oxygen scavenger (removes oxygen molecule from the plant tissue), thus preventing the oxidation by PPO. Another mechanism suggested by Mayer and Harel, (1979) is self-oxidation to prevent phenolic compound oxidation or reduced the enzymatically formed O-quinones to its diphenols precursor.

Several previous studies showed that AsA also had an antimicrobial effect on fresh-cut fruit such as jackfruit, apple and papaya (Acedo et al., 2012, Perez-Gago et al., 2006; Qi et al., 2011 and Tapia et al., 2008). These results match with the findings of this study, where the microbial load was significantly reduced when AsA applied to the artichoke bottoms. In the current study, apart

from the untreated sample (control), all the mesophilic counts followed the recommended limit (8 log CFU g-1) for fresh-cut vegetables **(**Ministere de l'Economie des Finances et du Budget, 1988; Cnerna-Cnrs, 1996). The lowest *E. coli* counts (3.51 log CFU g^{-1}) were found in the artichokes treated with Cg containing $CaCl_2$ after 9 d of storage. The overall contamination of *E. coli* was higher, as the initial microbial load was significant (~ 3 log CFU g^{-1}). Although the microbial counts gradually increased with storage period for all treatments and control, Cg coating of artichoke bottoms slowed down the growth of indicator organisms during cold storage, especially when $CaCl_2$ was added. The positive effect of Cg for reducing microbial growth could be due to their semi-permeable barrier ability for moisture and gas which leads to control of microbial growth (Bourtoom, 2008). Moreover, phenolic compounds of Cg such as salicylic acid could be responsible for antibacterial activity (Babalar et al., 2007). Our results showed that dipping artichoke bottoms in Cg loaded with $CaCl_2$ recorded the lowest yeast and mould count compared with other treatments and control, followed by $CaCl_2$ and Cg + AsA treatments. Also, for all the treatments, fungal growth was significantly lower in comparison to the untreated artichoke bottoms. It is worth noticing that, the only sample showing mould counts > 5 log CFU g^{-1}, (a recommended limit by Cnerna-Cnrs (1996)), was the untreated sample (control). The main phenolic compound of Cg is salicylic acid, and a previous study carried out by El-Mogy et al. (2019) indicated that postharvest treatment of strawberry fruit by salicylic acid reduced fungal decay development. The role of salicylic acid in reducing microbial growth might be due to its role in enhancing the amount of hydrogen peroxide in plants which acts as a stimulant to plant resistance systems against pathogen attack.

5. Conclusion

Our study suggested that Cg in combination with AsA or $CaCl_2$ can extend storage ability of artichoke bottoms by reducing weight loss, TPC, browning index, and decay by reduction of total mesophilic bacteria, psychrotrophic bacteria, and mould growth. Moreover, a reduction in the hazard of E. Coli contamination on artichoke bottoms during storage was a very welcoming result. The results also indicated that Vit C and TPC were preserved by the edible coating of Cg alone or in combination with AsA or $CaCl_2$. Salicylic acid was the main compound of the phenolic group in Cg, which has the role against bacterial growth. Our results suggest that Cg with $CaCl_2$ or AsA

treatments could be a useful application for maintaining artichoke bottoms quality during refrigerated storage for 6 up to 9 d. In conclusion, it can be said that use Cg coating supplemented with AsA and $CaCl_2$ has significant potential in enhancing the shelf life of artichoke bottoms and maintaining the postharvest quality of the vegetables. Future studies may also investigate if the edible coating can modify the atmosphere inside the packaging. Moreover, further research is required in adapting the *Cordia myxa* gum-based edible coating materials to commercial settings and scaling up the use of these novel methods of postharvest management and technology.

Conflict of interest statement

Authors declare no conflict of interests.

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