Impact of gum arabic and cactus mucilage as potential coating substances combined with calcium chloride treatment on tomato (Solanum lycopersicum L.) fruit quality attributes under ambient storage conditions

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ARTICLE

Impact of gum arabic and cactus mucilage as potential coating substances combined with calcium chloride treatment on tomato (*Solanum lycopersicum* L.) fruit quality attributes under ambient storage conditions

Fayez Sati Daraghmah and Tawfiq Qubbaj

Abstract: The current work investigates the impact of postharvest applications of calcium chloride ($CaCl_2$) in combination with either 10% gum arabic or 50% cactus mucilage on the quality parameters and storability of tomato fruit (Izmir variety), at ambient storage conditions [21 ± 1 °C, relative humidity (RH) 45% ± 2%]. The tomato fruits were dipped in 6% $CaCl_2$ for 10 min and then coated with either 10% gum arabic or 50% cactus mucilage for 3 min. During the time-course of storage, the fruit attributes, such as fresh fruit weight loss, fruit decay, firmness, titratable acidity (TA), total soluble solids (TSS), and color development were assessed. The results revealed a significant ($P \leq 0.05$) effect of fruit postharvest treatment with 6% $CaCl_2$ for 10 min combined with postharvest coating treatments with either 10% gum arabic or 50% cactus mucilage for 3 min on reducing fruit fresh weight loss, and decay percent of fruits. Fruit firmness, TA, and TSS were preserved compared with untreated fruit. In addition, treated fruits took more time to develop from pink to full red compared with untreated fruit. Hence, coating with natural substances combined with $CaCl_2$ preserved the overall quality parameters and enhanced the shelf life of tomato fruit even after three weeks of storage at ambient temperature.

Key words: fruit quality, natural substances, postharvest, fruit's edible coating.

Résumé : Les auteurs ont étudié les effets de l'application après récolte de $CaCl_2$ avec de la gomme arabique à 10 % ou du mucilage de cactée à 50 % sur les paramètres qualitatifs de la tomate (variété Izmir) et sur son entreposage à température ambiante (21 ± 1 °C, HR 45 % ± 2 %). Les tomates ont été plongées dix minutes dans une solution à 6 % de $CaCl_2$, puis enduites de gomme arabique à 10 % ou de mucilage de cactée à 50 % pendant trois minutes. Les attributs du fruit ont été évalués durant l'entreposage (diminution du poids frais, blettissement, fermeté, acidité totale, concentration de solubles totaux, couleur). Les résultats indiquent que le traitement après récolte réduit significativement ($P \leq 0,05$) la perte de poids frais et la proportion de fruits gâtés. La fermeté du fruit, l'acidité totale et la concentration de solides totaux demeurent inchangés, comparativement aux fruits non traités. Les fruits conditionnés prennent aussi plus de temps pour passer du rose au rouge. Par conséquent, recouvrir les tomates d'un enduit naturel après les avoir protégées avec du chlorure de calcium préserve les paramètres qualitatifs du fruit et en prolonge la durée de conservation, même après trois semaines d'entreposage à température ambiante. [Traduit par la Rédaction]

Mots-clés : qualité du fruit, substances naturelles, post-récolte, enduit comestible.

Introduction

Globally, tomato (*Solanum lycopersicum* L.) is one of the most widely consumed fresh vegetables and has been ranked as the second-largest grown vegetable (Kumar et al. 2020). It is also considered among the most important vegetable crops in Palestine, with an estimated annual cultivated area of ~891.8 ha, producing ~82 739 tons yearly (MOA 2018). Tomatoes are a good source of vitamin C, vitamin K, carotenoids, and different dietary minerals (i.e., iron and phosphorous) that

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are necessary for human health (Ülger et al. 2018). They are also the primary dietary source of the antioxidant lycopene, which is strongly linked to many health benefits, such as reducing the risk of heart disease and cancer (Story et al. 2010). Tomato fruits are classified as highly perishable and have considerable losses after harvest due to their climacteric ripening pattern, defined by the high respiration rate and increased ethylene production levels (Ali et al. 2013). During ripening, several biochemical processes that contribute to the overall changes in the organoleptic quality of fruits occur (Nasrin et al. 2008). For instance, the fruit display pectin degradation, degradation of cell wall, reduction in acidity, breakdown of carbohydrates into sugars, pigmentation, biosynthesis of volatile ester compounds. Inappropriate postharvest handling practices significantly influence fruit organoleptic quality changes during fruit ripening and storage. This generates an early deterioration of fruit texture, poor sensory quality, and short shelf life (El-Ramady et al. 2014). Therefore, maintaining high-quality fruits with extended shelf life via controlling the ripening process, respiration rate, and weight loss is essential to preserve fruit firmness and texture during storage (Arah et al. 2016). Research on the application of postharvest calcium chloride on many fruits and vegetables was found to conserve the firmness and reduce decay percentage, stabilizing membrane integrity, and forming Ca-pectate in the cell wall (Angeletti et al. 2010). Additionally, it acts as an ethylene inhibitor by interrupting ethylene biosynthesis, delaying the maturity and senescence of some climacteric fruits like tomato, bananas, apples, and strawberries (Senevirathna and Daundasekera 2016).

The edible coating on fruits using different natural substances was reported to reduce fruit decay by forming a semi-permeable film around the surface of fruits and improving the waxy cuticle (Gol et al. 2013). Gum arabic is a dried gummy exudate from the stem and the branches of *Acacia senegal* (Ali et al. 2010). It is composed of a mixture of polysaccharides and glycol proteins, used in industries due to its distinctive properties of film formation, emulsification and encapsulation (Ali et al. 2013). It was used to delay ripening, extend shelf life, and reduce fruit browning infection rate caused by mold (Kashif and Fahad 2013). The cactus mucilage is a complex polysaccharide, hydrophilic, which has the ability to create a barrier against water loss and gas exchange, and therefore enhance the postharvest life of many fruits when applied as an edible coating (Gheribi and Khwaldia 2019). To the best of our knowledge, no report has shown the usage of cactus mucilage as a coating substance on tomato fruit, while it has been tested on other fruit crops (Del-Valle et al. 2005). Furthermore, the combined effect of $CaCl_2$ and a coating substance, so far, has not been reported on the fruit of vegetable crops.

This study investigates the influence of postharvest applications of $CaCl_2$, in combination with gum arabic or cactus mucilage, as a potential edible coating substance. The quality attributes and shelf life of tomato fruit stored under ambient temperature conditions were evaluated.

Materials and Methods

Fruit material

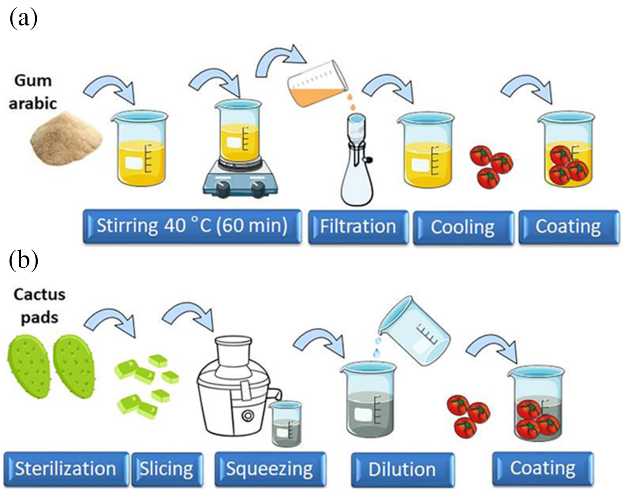
Tomato fruits (Izmir variety) were harvested at the breaker stage (i.e., the distal end of the fruits turns yellow) from a commercial farm in Tubas, at the northern part of the West Bank, Palestine. Tomato fruits with uniform size and free from physical damage, injury, and bruises were carefully selected for this study. Temperature and humidity were controlled throughout the storage period at 21 ±1 °C and a relative humidity (RH) of 45% ± 2 for up to 20 d.

Postharvest treatment

A 10% (*w*/*v*) of gum arabic coating solution was prepared by dissolving 100 g of gum arabic powder (Kapadia Gum Industries Pvt Ltd. MUMBAI – 400056, India) in 1000 mL of distilled water. The solution was heated at 40 °C for 60 min using a magnetic stirrer (Model SP 18420-26 Barnstead Thermolyne USA), then filtered to remove any undissolved impurities using a vacuum flask. The solution was allowed to cool to room temperature before using (Ruelas-Chacón et al. 2017). Cactus (*Opuntia ficus-indica*) pads were harvested from a local farm and immediately sterilized with distilled water and 1% chloride. They were then peeled, sliced into 1 cm cubes, and squeezed by fruit juicers (GJE5437, 800 WTT model Jepas, China). The juice was diluted with distilled water (2:1) (*w*/*v*) to obtain cactus mucilage. A 6% (*w*/*v*) $CaCl_2$ solution was prepared by dissolving 60 g of edible grade $CaCl_2$ (Wei Bang Chemical Limited Company, Xiamen Ditai chemicals China) in 1000 mL of distilled water. The solution was heated by a magnetic stirrer at 40 °C for 20 min (Fig. 1).

Tomato fruits were divided into six sets; each consisted of 95 fruits. Three fruit sets were first dipped in 6% $CaCl_2$ for 10 min, then kept air-drying for 60 min (Fig. 2). Two sets were further used for in-combination coating treatments by dipping in 10% gum arabic for 3 min or in the 50% cactus mucilage for 3 min. Other fruit sets were dipped for 3 min in 10% gum arabic or in 50% cactus mucilage without $CaCl_2$. The last fruit set served as a control, where the fruits were dipped in distilled water. The fruit quality parameters [i.e., weight loss, color development, firmness, TSS, TA, and sugar/acid ratio (TSS/TA)] were recorded before treatment (day-0) and then at four-day intervals. Treated fruits were packed in plastic boxes covered with polyethylene film and stored in a controlled walk-in storage room with a maintained RH of 45% ± 2% and temperature at 21 ± 1 °C for up to 20 d.

Fig. 1. Schematic of the procedure used for the preparation of the coating solution (*a*) gum arabic coating solution 10% (*w*/*v*), (*b*) cactus (*Opuntia ficus-indica*). [Color online.]



Analysis of quality parameters

Color development

The change in color of tomato fruits was assessed using a Chroma meter (KONICA MINOLTA). Chromaticity parameters *L* (brightness), a+ or a− (red or green), b+ or b− (yellow or blue) were measured according to the CIE Lab system. *L* (lightness of brightness) a^* and b^* values were recorded from both sides of the tomato skin from 2 tomato fruits per replicate. The chrome value (C^*) and the hue angle (*h*) were also calculated following the formulas (Tijskens and Evelo 1994).

$$C^* = \sqrt{(\mathrm{a}^2 + \mathrm{b}^2)}$$

$$h = [\tan -1(b^*/a^*)]$$

The results were recorded at day 0 and every four-day interval until the end of the experiment.

Weight loss

Weight loss of tomato fruits was tracked by measuring the weight of fruits on the first day and every four days by a digital balance (Analytical Digital Balance Single Pan). The weight loss was calculated as percent using the following equation (Nirupama et al. 2010)

$$\%\,\text{weight loss} = \left(\frac{\text{initial weight} - \text{final weight}}{\text{initial weight}}\right) \times 100$$

Fruit decay

Fruit decay was determined by visual observation. The various fruit peel spots and rotting developments were observed, and the percent of decay was calculated for both treated and untreated fruits using the following formula (Nirupama et al. 2010)

$$\%\,\text{fruit decay} = \left(\frac{\text{fruit decay}}{\text{initial fruit}}\right) \times 100$$

Firmness measurements (N)

A digital penetrometer Model Lutron FR-5120 (QA Supplies LLC, Norfolk, VA, USA) equipped with a 6 mm diameter tip was used to measure firmness. The tip was pushed into the fruit after removing a small patch of skin. A standard pressure was used to puncture the fruit to obtain a uniform application of force and firmness. Firmness measurements were taken on both sides of every fruit after being peeled (Kumah and Olympio 2011). The firmness reading was measured in N force.

Total soluble solids (TSS; °Brix)

Total soluble solid (TSS) contents of juice from tomato were measured using a digital refractometer, model Milwaukee MA871 (Milwaukee Instruments, Inc., Rocky Mount, NC, USA). The results were expressed as °Brix (Nirupama et al. 2010).

Titratable acidity (TA)

Tomato juice (15 mL) was diluted with 85 mL of distilled water. Titratable acidity was quantified by titration method using 0.1 N NaOH to an endpoint pH (8.1) (Islas-Osuna et al. 2010). The result was expressed as a citric acid percentage using the following formula

$$\%\,\text{citric acid} = \frac{(\text{mL NaOH used}) \times (0.1\,\text{N NaOH}) \times (\text{milli equivalent factor for tomato}) \times (100)}{\text{g of sample}}$$

milli equivalent factor = 0.0064 g.

Ripening Index

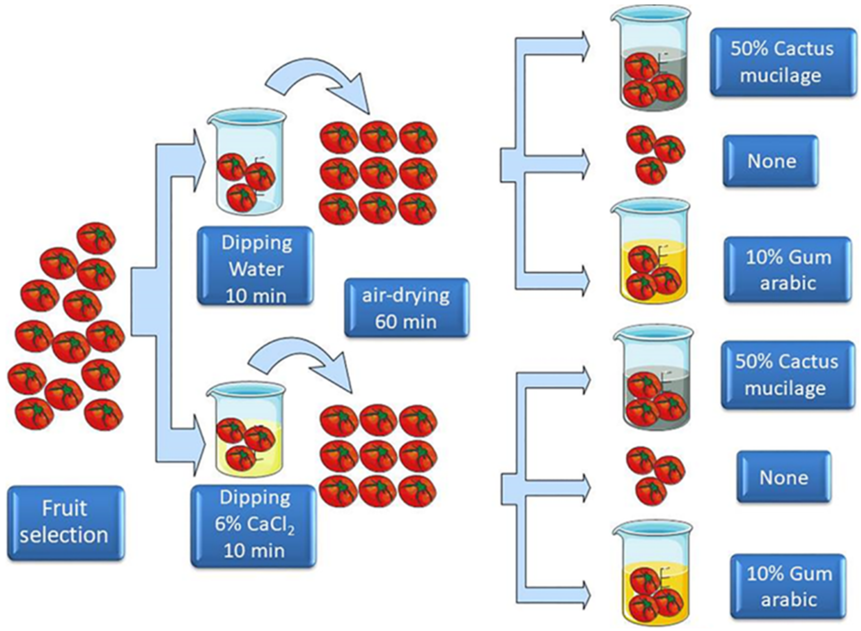
The ripening index was calculated as the ratio of measured TSS to TA of tomato juice as described by Hamid et al. (2011), using the following formula

$$\text{ripening index} = \text{measured TSS}/\text{measured TA}$$

Data collection and statistical analysis

A complete randomized design (CRD) was used, with three replications for each treatment. Each replicate contains 30 fruits. However, for weight loss parameters, five fruits per treatment were used. The collected data were statistically analyzed using the analysis of variance (ANOVA) at $P \leq 0.05$ by the SAS statistical software (SAS University Edition, 2016). Duncan's multiple range test

Fig. 2. Dipping and edible coating treatments (untreated, $CaCl_2$, gum arabic, cactus mucilage, and its combinations) applied on tomato fruits. [Colour online.]



was used for evaluating mean separation at 5% level of probability.

Results

Effect of postharvest treatments on physio–chemical characteristics of tomato fruits

Fruit color development

During ambient temperature storage conditions, the color change of tomato fruits showed a typical pattern of development in control and treated fruits. However, some changes in the color components during the storage were observed. The red color increased significantly after 8 d in control (untreated) fruits compared to other different treated fruits, where the a^* value was changed from negative (green color) to positive (red color) in the control. In addition, the lightness (L^*) and b^* values (yellow color intensity) were significantly lower in the control group than in other treatments. The same patterns were also found in the hue angle values of the control. The non-coated fruits showed significantly lower hue angle values (Fig. 3*d*). The hue angle indicated that the coated tomato fruits are not pure red; a hue angle of 55.5° is a reddish–yellow color, whereas the closer to 90° would mean that the tomato is yellow, 0° indicates completely red). However, no major changes in color development were observed in other treatments as the fruits have remained predominately at the mature breaker stage (pink to light red). The chroma value indicates the degree of saturation of color and is proportional to the strength of the color. A change was found in the chroma between the control and coated tomato fruit; the lowest chroma value was found in control (non-treated) tomato fruits (Fig. 3*e*).

The in-combination coating treatments of 6% $CaCl_2$ and 10% gum arabic or 50% cactus mucilage were found to significantly ($P \leq 0.05$) delayed color development of tomato fruits compared to other none in-combination treatments. This positive effect of postharvest application of the in-combination coating on slowing down the color development of tomato during ambient storage was reflected in the significant reservation of color parameters L^* (brightness), a^* (red color intensity), b^* (yellow color intensity), hue (h), and chroma (C^*) compared with the control (untreated) fruit and other alone treatments, even at 16 d of storage (Figs. 3*a*–3*e*).

Weight loss

All treatments showed gradual losses of tomato fruit weight during storage (Figs. 4*a* and 4*b*). Results also revealed that the change in weight loss started on day four and continued until the end of the experiment after 20 d, in both treated and untreated fruits. Weight loss of untreated tomato fruits was significantly ($P \leq 0.05$) higher than treated fruit after the fourth day up to the end of the storage period. However, postharvest application of 6% $CaCl_2$-treatments in-combination with either 10% gum arabic or 50% cactus mucilage significantly ($P \leq 0.05$) reduced the fruit weight loss compared to other solo treatments and control (untreated fruits) during the storage period (Fig. 4*b*).

Fruit decay

Incidence of fruits decay was observed after 12 d of storage and gradually increased in all fruits with the

Fig. 3. Effect of natural substance postharvest combination treatments with $CaCl_2$ on the color development aspects of tomato fruit during storage at room temperature (21°C), including luminosity [L-scale (A)], a-index (B), b-index (C), hue angle (D), and chroma (E). Each point represents the mean of three biological replicates (± standard division). The means followed by the same letter are not significantly different (Duncan's multiple range test, $P \leq 0.05$). [Colour online.]

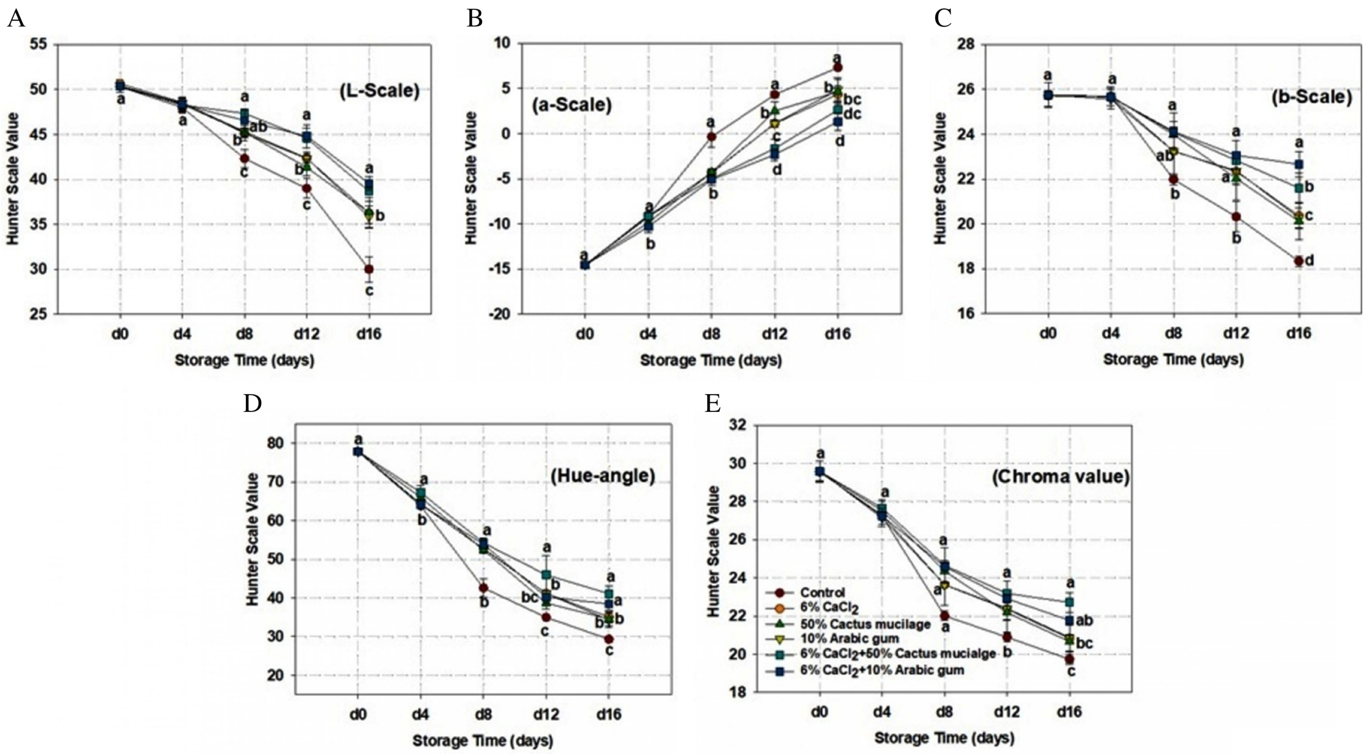
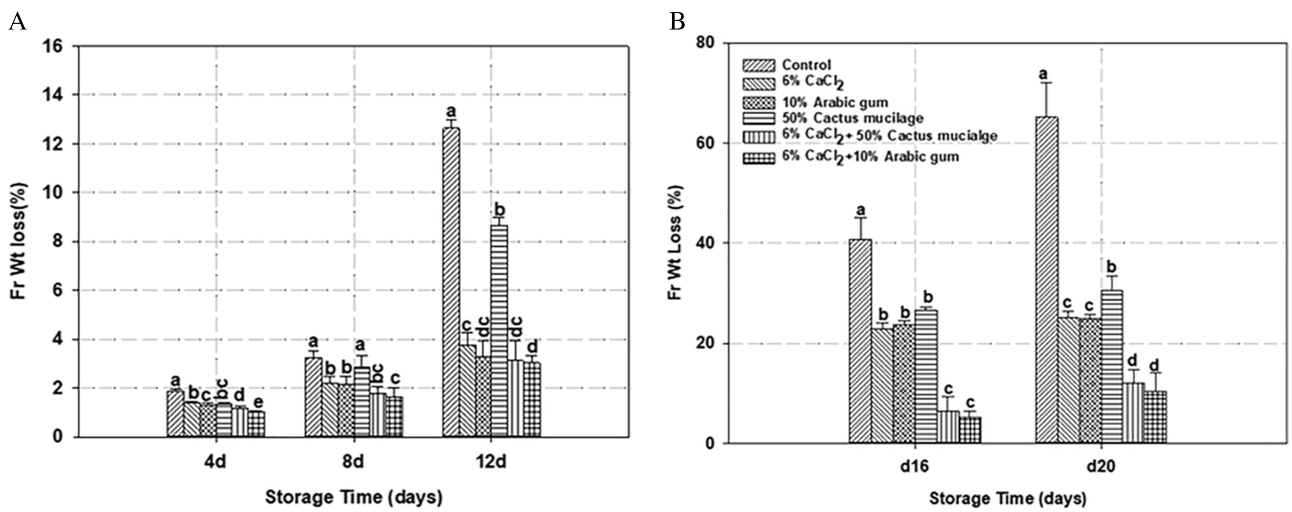


Fig. 4. Effect of natural substance postharvest combination treatments with $CaCl_2$ on the fruit weight loss trait of tomato fruits during storage at room temperature (21°C) for (A) 4, 8, and 12 d, and (B) 16 and 20 d. Each value represents the mean of five biological replicates (± standard division). The means followed by the same letter are not significantly different (Duncan's multiple range test, $P \leq 0.05$).



storage period progression (Fig. 5). Coating fruits with different substances significantly reduce fruit decay compared to the control group. After day 16 of room temperature storage, the fruit decay percentage increased in all treated and untreated tomato fruit. However, the results recorded a lower decay rate in fruits

Fig. 5. Effect of natural substance postharvest combination treatments with $CaCl_2$ on the decay percentage of tomato fruits during storage at room temperature (21°C). Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are not significantly different (Duncan's multiple range test, $P \leq 0.05$).

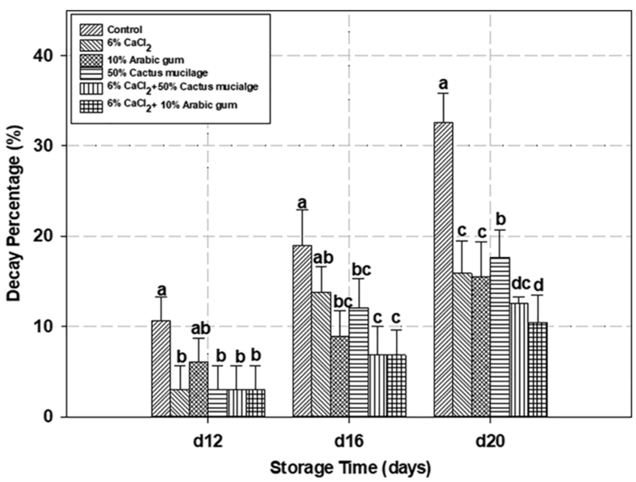
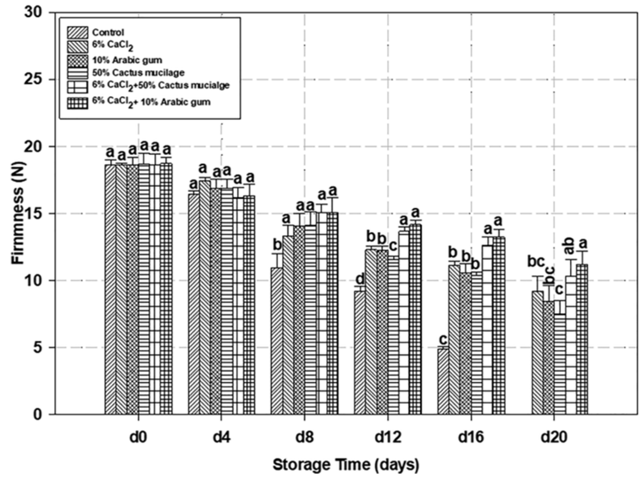


Fig. 6. Effect of natural substance postharvest combination treatments with $CaCl_2$ on the firmness (N) of tomato fruits during storage at room temperature (21°C). Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are not significantly different (Duncan's multiple range test, $P \leq 0.05$).



coated with 6% $CaCl_2$-treatments and combined with 10% gum arabic or 50% cactus mucilage than other treated and control fruits (Fig. 5).

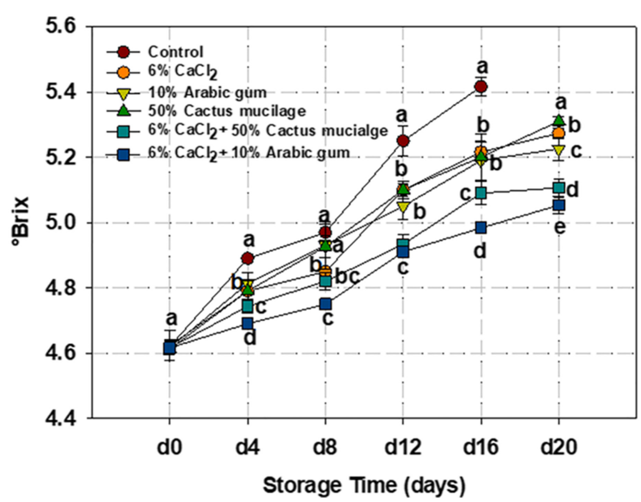
Firmness

Coating fruits with different natural substances combined with pre-dipping in 6% $CaCl_2$-treatments showed a significant positive effect on preserving tomato fruit firmness compared to control fruits (Fig. 6). The firmness of control fruits was significantly lower over the storage period. However, all samples showed a gradual loss of firmness during storage. On day 8, fruit firmness was significantly ($P \leq 0.05$) less in control (untreated) fruits compared to different treated fruits. Moreover, the firmness of fruits treated with 6% $CaCl_2$ in-combination with either 10% gum arabic or 50% cactus mucilage preserved fruit firmness compared to other treatments until the experiment was terminated (Fig. 6).

Total soluble solids (TSS)

In the current study, no significant difference in TSS was observed along with all treatments at day zero. However, higher significant differences ($P \leq 0.05$) were observed in the TSS content of non-treated tomato fruits (control), compared to other treated fruits during the storage period at ambient conditions (Fig. 7). Although there was a gradual increase in TSS during the entire storage period in all fruits, a significant ($P \leq 0.05$) reduction in TSS was recorded in fruit treated with 6% $CaCl_2$ in combination with either 10% gum arabic or 50% cactus mucilage coating compared to other treatments. No significant differences ($P \leq 0.05$) were found in TSS between

Fig. 7. Effect of natural substance postharvest combination treatments with $CaCl_2$ on the total soluble solids (°Brix) of tomato fruits during storage at room temperature (21°C). Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are not significantly different (Duncan's multiple range test, $P \leq 0.05$). [Colour online.]



fruits dipped in either of 6% $CaCl_2$, 10% gum arabic or 50% cactus mucilage single treatment. At the end of the storage period, the significantly lowest TSS was recorded in fruits coated with 10% gum arabic combined with 6% $CaCl_2$ dipping treatment.

Titratable acidity (TA)

The TA values of coated and non-coated fruit during storage gradually decreased with the storage period

Fig. 8. Effect of natural substance postharvest combination treatments with $CaCl_2$ on the titratable acidity (TA) of tomato fruits during storage at room temperature (21°C). Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are not significantly different (Duncan's multiple range test, $P \leq 0.05$).

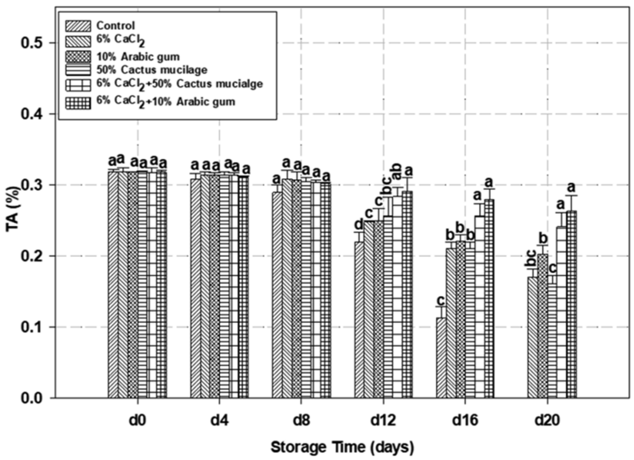
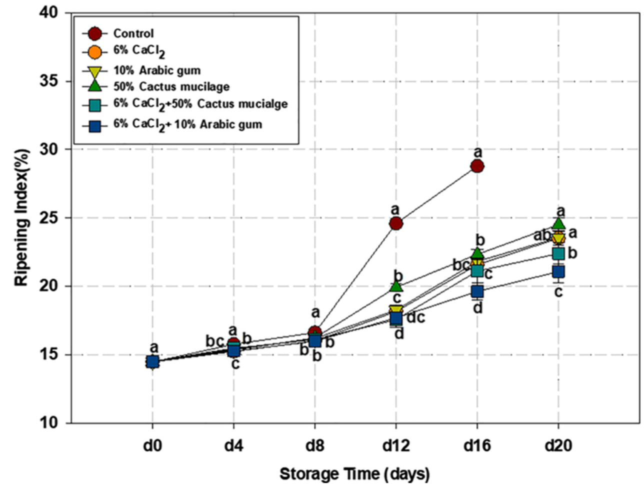


Fig. 9. Effect of natural substance postharvest combination treatments with $CaCl_2$ on the ripening index of tomato fruits during storage at room temperature (21°C). Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are not significantly different (Duncan's multiple range test, $P \leq 0.05$). [Colour online.]



during all treatments (Fig. 8). However, no significant difference ($P \leq 0.05$) in TA was observed until day 8 of storage. While, at day 12 of storage until the termination of the experiments (day 20), the TA value was significantly higher ($P \leq 0.05$) in 6% $CaCl_2$ treatments in-combination with 10% Arabic gum or 50% cactus mucilage coating treatments compared to other coating treatments and untreated fruits (control) (Fig. 8).

Ripening index

The ripening index increased within the storage period for all treated and untreated fruits (Fig. 9). However, in untreated fruits (control), TSS: TA ratio demonstrated a significantly ($P \leq 0.05$) sharp increase from 8 d of storage until the deterioration of fruits at day 16. On the other hand, coated fruits had minor changes in TSS: TA ratio after 8 d of storage until the deterioration of the fruit at day 20 (Fig. 9).

Cross comparison between treatments

The cross-comparisons between treatments were established to distinguish a potential treatment that shows better fruit shelf-life qualities. Accordingly, the slope of the changes in the quality traits curve for each treatment was calculated. Then, the slopes were statistically compared to disclose any significant differences at 95% confidence. Statistical analysis of slope profile suggested that all treatments performed significantly better than the control for all evaluated quality traits, excluding the changes in color quality traits of hue and chroma values due to treatment with cactus mucilage that was insignificant relative to control fruits (Supplementary Table S1[1]).

Relative to $CaCl_2$, the treatments with arabic gum and cactus mucilage alone did not display significant differences in fruit quality traits, with some exceptions. The arabic gum treatment considerably delayed the ripening process by accumulating less sugar and higher acid levels, comparing with $CaCl_2$ treated fruit. However, cactus mucilage treatment was less efficient than $CaCl_2$ treated fruit, in terms of generating significantly softer fruit with a more enhanced ripening index. The mutual treatment of $CaCl_2$ with either arabic gum or cactus mucilage displayed much more visible differences. Relative to the individual $CaCl_2$ treatment, fruits exposed to the mutual treatments exhibited considerably better weight loss characteristics, extended color index values (L, b, and chroma), and acid content. On the other hand, they significantly displayed less firmness, a-color index, sugar, and TSS: TA ratio (Supplementary Table S1[1]). Despite that, the fruit treated with $CaCl_2$–cactus mucilage showed significantly higher hue values and less fruit decay. No significant differences were noted between the individual $CaCl_2$ treatment and the mutual $CaCl_2$–arabic gum treatment for these two quality traits.

The majority of fruit quality traits slope did not show significant differences between fruits exposed to individual arabic gum and cactus mucilage treatments, excluding some traits. For instance, arabic gum-treated fruits exhibited significantly better firmness, higher sugar,

[1]Supplementary data are available with the article at https://doi.org/10.1139/cjps-2021-0164.

reduced acid levels, and less fruit decay than cactus mucilage-treated fruit.

Relative to the individual arabic gum or cactus mucilage treatment, the mutual treatments of $CaCl_2$–arabic gum or $CaCl_2$–cactus mucilage showed remarkable differences. For example, fruit exposed to $CaCl_2$–arabic gum or $CaCl_2$–cactus mucilage exhibited significantly better weight loss characteristics, extended color aspects, and higher acid levels. However, they exhibited considerably less firmness, sugar content, TSS: TA ratio, and fruit decay.

Finally, the $CaCl_2$–cactus mucilage treated fruits demonstrated significantly better firmness qualities, higher sugar content, lower acid levels, reduced TSS/acid ratio, and less fruit decay.

Discussion

Effect of postharvest treatments on physio–chemical characteristics of tomato fruits

Fruit color development

Tomato fruit color is one of the most critical, complex fruits quality parameters, and it is the first sensory attribute consumers use to judge fruit acceptability (Barret et al. 2010). The characteristic red pigmentation of ripe tomato fruit results from the de novo synthesis of carotenoids, mainly lycopene and β-carotene, associated with the change in fruit color from green to red (Bouzayen et al. 2010). Coating substance was found to delay chlorophyll degradation and lycopene synthesis, as well as delay the ripening process compared to uncoated fruits (Gheribi and Khwaldia 2019). However, this delay in fruit color development could be attributed to the modified surrounding atmosphere; the fruits are placed in, and by reducing the concentration of oxygen (O_2) and increasing the concentration of carbon dioxide (CO_2). This leads to reducing respiration and ethylene production rate in climacteric fruits (Pila et al. 2010), thus, delaying ripening and its associated changes in fruit color development. The present results indicated a delay in color changes in tomato fruits treated with 6% $CaCl_2$ treatments in combination with 10% gum arabic or 50% cactus mucilage, which might result from decreased biosynthesis carotenoids and preservation of chlorophyll content. These findings are consistent with the previous research, in which gum arabic coatings delayed color changes in tomato (Ali et al. 2010) and guava (Gurjar et al. 2018).

Weight loss

The loss of weight in fruits occurred during the transpiration process through the fruit's surface, a normal metabolic process resulting in shriveling and deterioration of the fruit. It depends on the water vapor pressure gradient between the surrounding atmosphere and the fruit tissue (Baldwin et al. 1999). In this study, the reduction in weight loss was probably due to the effects of the coating substance (gum arabic and cactus mucilage) and the $CaCl_2$ combination treatments as a physical water loss barrier. Thereby restricting water transfer and thus delaying dehydration and reduced water losses (Pila et al. 2010). Moreover, $CaCl_2$ treatments were found to delay ripening and extend storage life (Irfan et al. 2013) by reducing the concentration of O_2 and increasing the concentration of CO_2, which helped in delaying senescence. Reducing respiration and ethylene production rate in climacteric fruits such as tomato fruits reduced the rate of ripening (Pila et al. 2010).

Fruit decay

Fruit decay is a natural phenomenon associated with the ripening process and postharvest diseases (Khaliq et al. 2015). The current results indicated that coating played a significant role and calcium chloride combination treatments reduced fruit decay. Calcium chloride was found to play a major role in strengthening and thickening of the middle lamella of the cell wall through increased formation and deposition of Ca-pectate in the cell wall (Gol et al. 2013). During the fruit ripening process under long-term storage conditions, several microorganisms such as fungi and bacteria were associated with some enzymatic change activities. Such factors trigger damage to the fruits and deteriorate the middle lamella, particularly plant enzymes associated with the senescence process (Zapata et al. 2008). Therefore, delaying fruit ripening will reduce fruit decay, as fast ripening and microbial incidence are among the main causes of fruit decay and postharvest deterioration.

Several research findings agree with the results of our current study. Dipping apple fruit in $CaCl_2$ reduced postharvest decay and delay senescence compared to control (untreated) fruit (Hussain et al. 2011). Khaliq et al. (2015) reported that coating mango fruit with gum arabic protected the fruit from pathogen infection and suggested coating from a film on the mango surface. This film acts as a barrier to protect the fruit.

Firmness

Fruit firmness is one of the most important attributes that affect the postharvest quality and fruit's storability. The current results indicated that untreated fruits soften more rapidly as compared to treated fruits. These changes were caused due to deterioration in the cell wall structure, composition and intracellular components during the ripening process and storage (Harold et al. 2007). This change has been observed in a wide range of fruits, including tomato (Ruelas-Chacon et al. 2017), mango (Khaliq et al. 2015) and plums (Valero et al. 2013). Postharvest application of calcium chloride was found to act as a binding agent in the cell wall to form calcium pectate, which increases the rigidity of the middle lamella and cell wall. It also inhibited the cell wall degrading enzyme activity, so the cell wall's outer membrane becomes stronger and more rigid (Pila et al. 2010). Coating substances (gum arabic and cactus mucilage) combined with $CaCl_2$ dipping treatments could have helped in creating a modified atmosphere surrounding the fruit's surface. Consequently, elevating the CO_2 and decreasing the fruit respiration rate (Ali et al. 2013), limited the activity of softening-related biochemical enzyme activity such as; hydrolases, pectinesterase, and polygalacturonase (Arah et al. 2016; Ruelas-Chacon et al. 2017). Therefore, maintaining fruit firmness during storage.

Total soluble solid (TSS), titratable acidity (TA) and ripening index

Higher TSS concentration is directly proportional to ripening (Kulkarni et al. 2010). During the ripening of tomato fruits, the TSS level rises due to the hydrolysis of starch into monosaccharides, glucose, fructose, and sucrose (Maldonado-Celis et al. 2019). However, fruit coating displayed a significant ($P \leq 0.05$) delay in the increment changes of TSS concentration and delayed the ripening process compared to uncoated fruits. This delay in fruit ripening could be attributed to the modified semi-permeable film around the fruit, modifying the atmosphere by reducing O_2 concentration and increasing CO_2 concentration, thus decreasing the respiration and ethylene production rate in climacteric fruits (Pila et al. 2010). Therefore, it helps delayed ripening and the associated changes in TSS elevation (Yaman and Bayoindirli 2002). A similar to the presented TSS change pattern was found in tomato fruit coated with gum arabic (Ali et al. 2010; Ali et al. 2013), or with Aloe vera (García et al. 2014). The significantly lower level of TA in untreated fruits (control) compared to the 6% $CaCl_2$ dipping either combined with gum arabic or cactus mucilage coating fruit suggested that the coating may have delayed the ripening process by providing a modified atmosphere around the fruit surface and creating a barrier against O_2 and CO_2. Thereby leading to reducing respiration rate and associated climacteric ethylene peak (Ali et al. 2010).

In addition, the ripening index is an important indicator of the quality evaluation of fresh fruit and vegetables. The highest significant value recorded in untreated fruit could be attributed to the ripening process of fruit associated with ethylene production and the conversion of starch to sugar and acidity, accelerating the ripening process (Ibrahim 2005). The fruit's aroma, flavor, and taste development are also attributed to the accumulation of sugar and organic acid in the vacuoles (Baldwin et al. 1999). The result revealed that coating fruit with natural plant substances (gum arabic and cactus mucilage) and $CaCl_2$ treatments required more time to reach full maturity. In addition, natural substances such as gum arabic and cactus mucilage coating will reduce the respiration rate, thus delaying the utilization of organic acids and the ripening process in fruit (Yaman and Bayoindirli 2002).

Conclusions

This study clearly demonstrates that tomato fruit postharvest dipping in 6% $CaCl_2$ and coated with either 10% gum arabic or 50% cactus mucilage positively impacted the tomato fruit's physical and chemical properties, and maintained the overall quality of fruit during the ambient storage conditions. A significant delay in the change of fresh fruit weight, firmness, TA, TSS, and color development was found during storage at 21 ± 1°C compared to the uncoated control fruit. Coating with natural substances could act as a semi-permeable film around the surface of the fruit, improving the waxy cuticle and modifying the atmosphere by reducing O_2 concentration and increasing CO_2 concentration. By decreasing the respiration and ethylene production rate in tomato climacteric fruit, we were able to delay the fruit ripening during storage, and preserve major fruit quality attributes up to 20 d at ambient temperature. The combined application of calcium chloride with a gum arabic or a cactus mucilage coating is a promising environmentally friendly and cost-effective postharvest treatment that might be applied to other widely consumed fruits and vegetables. This opens up future research to investigate the effective combination to secure spacious antibacterial activity, preserve the quality, extend the shelf life of fruits, reduce postharvest deterioration, and reduce packaging waste and fruit wastage.

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