Journal of Applied Botany and Food Quality 94, 100 - 107 (2021), DOI:10.5073/JABFQ.2021.094.012

[1]Department of Plant Protection, Ministry of Agriculture, Palestine
[2]Department of Plant Production and Protection, Faculty of Agriculture and Veterinary Medicine, An-Najah National University, Palestine

Effect of calcium chloride postharvest treatment in combination with plant natural substance coating on fruit quality and storability of tomato (*Solanum lycopersicum*) fruits during cold storage

Fayez Sati[1], Tawfiq Qubbaj[2*]

(Submitted: September 8, 2020; Accepted: May 3, 2021)

Summary

In this study, the impact of postharvest treatments with calcium chloride ($CaCl_2$) in-combination with postharvest coating treatments with plant natural substance arabic gum or cactus mucilage on the quality and storage life of tomato fruits during cold storage (10 ± 1 °C, RH 85% ± 3) was evaluated. Results of dipping tomato fruits in 6% $CaCl_2$ for 10 minutes combined with postharvest coating treatments with either 10% Arabic gum or 50% cactus mucilage for 3 minutes showed significant ($p<0.05$) higher value of fruit firmness, titratable acidity, reduce the percentage of weight loss and percent of decayed fruits. Treated fruits took longer to change color from pink to red compared with non-treated fruits. This study showed that dipping tomato fruits in 6% $CaCl_2$, or coating with different natural substances alone or in combination with $CaCl_2$, enhances tomato fruits' physical and chemical properties. Moreover, preserving tomato fruits can be preserved for a longer time compared with control fruits and maintain the overall fruit quality.

Keywords: Edible coating, arabic gum, cactus mucilage, storage life, physio-chemical properties, firmness, titratable acidity.

Introduction

Tomato (*Solanum lycopersicum* L.) of the Solanaceae family is one of the most grown and fresh consumed vegetables worldwide (Adato et al., 2009). They have a high nutritional value of vitamins, minerals, natural antioxidant compounds and amino acids. In addition, several other beneficial health-related substances were found in tomatoes, such as carotenoids, lycopene and β-carotene, which have been correlated with reducing risk of cancer and some cardiac diseases in humans (Borguini and Torres, 2009).

Tomato is classified as a climacteric and highly perishable fruit with a high respiratory peak associated with a high ethylene production rate after harvest (Ali et al., 2013), resulting in a short shelf life of usually one to two weeks (Kapsiya et al., 2015). During ripening, tomato's physical properties and chemical composition change dramatically, affecting appearance, color, firmness, flavor, as well as the contents of phenolic, flavonoids and ascorbic acid (García et al., 2014; Ali et al., 2013). Therefore, susceptibility to substantial postharvest quality reduction of tomato fruits during handling, transportation, storage and marketing is high (Nasrin et al., 2008). Several postharvest techniques have been applied to manage fruit ripening by reducing the respiration rate and associated ethylene synthesis, such as controlled atmosphere storage, modified atmospheric gas composition, temperature and humidity control. However, these techniques are expensive (Baldwin et al., 2000).

Edible coatings have been considered as an eco-friendly and cost-efficient alternative technology to preserve quality and enhance agricultural commodities' shelf life (Hernalsteens, 2020). Edible coating of fruits provides several benefits, such as preserving the internal gas composition in tomato, mango, strawberry and guava (Zegbe et al., 2015; Dhall, 2013). They would form a semi-permeable barrier to gases, and water vapor on fruits surface, thus reducing weight loss, enabling the controlled release of bioactive compounds, enhancing the antioxidant activity, total phenolic contents and leads to preserving the quality attributes of fruits during storage (Hernalsteens, 2020; Ali et al., 2010). *Aloe vera*, arabic gum, cactus mucilage and guar gum have been used on tomato (Ali et al., 2013; Ali et al., 2010; Al-Juhaimi, 2012; García et al., 2014). Arabic gum is dried gummy exudates from the stem and the branches of *Acacia senegal* (Ali et al., 2010) and is composed of a mixture of polysaccharides and glycol proteins. It is used in industries for film-forming and encapsulation (Ali et al., 2013). It was also used to delay fruit ripening, extend the shelf life, and reduce fruit browning in guava, strawberry and apple fruits (Gurjar et al., 2018; Kashif and Fahad, 2013; El-Anany, 2009). Cactus mucilage is a complex hydrophilic polysaccharide found in *Opuntia ficus*-indica pads, that has the potential to create a barrier against water loss and gas exchange. Therefore, it could enhance postharvest life of many fruits when applied as an edible coating (Gheribi and Khwaldia, 2019).

According to our best of knowledge, no records are showing the usage of cactus mucilage as a coating substance on tomato fruits so far, while it has been tested on as an edible coating on strawberry (Del-Valle et al., 2005) and guava fruits (Zegbe et al., 2015). It has been demonstrated, that cactus mucilage has a positive impact on extending shelf life, maintaining some quality parameters as firmness and delaying fruit skin color development.

Postharvest application of calcium chloride on many fruits and vegetables found to delay softening by increasing rigidity of the middle lamella and act as a binding agent in the cell wall to form calcium pectate, which helps conserve the quality and increases the storage life of fruits and make them firmer (Mehmet et al., 2016; Gao et al., 2020). Several researchers reported the benefits of edible coating of fruits with natural substance and calcium chloride ($CaCl_2$) treatment (Abbasi et al., 2013; Senevirathna and Daundasekera, 2010), but none of them used arabic gum or cactus mucilage in combination with $CaCl_2$ as an edible coating for the preservation and extension of storage life of fresh tomato fruits. The current work aimed to study the effect of several novel combinations of edible coating substances as arabic gum or cactus mucilage and $CaCl_2$ postharvest dipping treatments on tomato fruits' physicochemical properties under cold storage.

Material and method

Plant materials and postharvest treatments

Tomato fruits cultivar *Izmir* were harvested at breaker stage (i.e. the distal end of the fruits just turns yellowish ring) from a commercial farm in Tubas-City, the northern part of West Bank, Palestine. Immediately after harvesting, all fruits were transported and careful-

* Corresponding author

ly handled to the National Agricultural Researcher Center (NARC), Ministry of Agriculture in Qabatya, Palestine. Only firm and well-developed fruits with uniform medium size, free from disease, injures, and bruises, were selected for further use in the experiments.

Dipping solutions preparation

Calcium chloride $CaCl_2$ 6% (w/v) solution was prepared by dissolving 60 g of edible grade $CaCl_2$ (Wei Bang Chemical Limited Company, Xiamen Ditai chemicals China) in 1000 ml distilled water. The solution was constantly stirred using a magnetic stirrer (Model SP 18420-26 Barnstead thermolyne USA) for 30 min until fully dissolved. Arabic gum solution 10% (w/v) was prepared by dissolving 100 g of arabic gum powder (Kapadia Gum Industries Pvt Ltd. MUMBAI - 400056, India) in 1000 ml distilled water. The solution had been stirred at a constant heat of 40 °C for 60 min on a magnetic stirrer (model SP 18420-26 Barnstead thermolyne USA), then filtrated through cheesecloth and filter paper (pore size of 5 µm) to remove any undissolved material. The solution was allowed to cool to room temperature before use (RUELAS-CHACÓN et al., 2017). Cactus mucilage extract (2/1) (w/w) was freshly prepared from Cactus *opuntia ficus*-indica pads harvested from plants in Tubas, Palestine. Pads were cleaned with 1% chloride, distilled water, then peeled and sliced into 1 cm cubes. Thereafter, squeezed by fruit juicers (GJE5437, 800wtt model Jepas, China) and diluted with distilled water by adding half the weight to obtain cactus mucilage (2:1) (w/w) (ZEGBE et al., 2015).

Treatments and experimental work

Selected fruits of the same size shape and free from visual damage or defects were randomly divided into six treatment groups. Each treatment was triple replicated and consisted of 90 fruits per replicate. A separate group of 15 fruits per treatment was used for weight loss assessment. Single coated postharvest fruit dipping treatments were applied as; (i) 6% $CaCl_2$ for 10 min. (ii) 10% arabic gum (w/v) for 3 min. (iii) Cactus mucilage (2/1) (w/w) for 3 min. Double coated postharvest fruit dipping treatments were applied as; (i) 6% $CaCl_2$ for 10 min, air-dried for 30 min at room temperature, then followed by another dipping in 10% arabic gum (w/v) for 3 min. (ii) 6% $CaCl_2$ for 10 min, air-dried for 30 min at room temperature, then followed by another dipping in 50% Cactus mucilage (2/1) (w/w) for 3 min., (iii) distilled water for 3 min served as a control. Single and double-coated postharvest treated fruits were left to air-dried for 30 min at room temperature before storage. Treated fruits were packed in plastic boxes covered with polyethylene film and stored in a controlled walk-in cold storage room with relative humidity (RH) of 85% ± 3 and temperature at 10 ± 1 °C for 35 days.

Postharvest fruit quality assessment

Fruit quality parameters, such as flesh firmness, physical weight loss, total soluble solids (TSS) and titratable acidity (TA) were evaluated on the date of the experiment (zero-day) before treatments, and every four days post the experiment first date for 35 days. Three fruits were selected randomly from every replicate per treatment used for the assessment.

Weight loss (%)

The same fruit was weighed every four days and the difference in weight loss was expressed in percentage on a fresh weight basis following the standard method; the percent of weight loss of tomatoes fruit sample was calculated using the following formula (PILA et al., 2010):

$$\text{Percent of weight loss} = \left(\frac{\textit{initial weight - final weight}}{\textit{initial weight}}\right) \cdot 100\%.$$

Decay percentage

Fruit decay was determined by visual observation. The various fruits peel spots and rotting development were observed, and the percent of decay was calculated for both treated and non-treated fruits following the formula (PILA et al., 2010).

$$\text{Percent of decay percentage} = \left(\frac{\textit{decay fruit}}{\textit{initial fruit}}\right) \cdot 100\%.$$

Color development

Colorimetric measurements of the tomato fruit skin colour were determined for three fruits per replicate per treatment from both sides of each fruit using a Chroma meter (KONICA MINOLTA) Hunter. 'L', 'a' and 'b' values measured light reflection and intensity from white to black, green to red and blue to yellow, respectively (VOSS, 1992).

Fruit firmness

Fruit firmness was measured using a digital penetrometers device (Lutron FR-5120) with 6 mm steel tip head to measure the average amount of force needed to puncture the fruit's flesh. The steel cylinder tips were applied to opposite sides of each tomato fruit on an area with the skin removed to expose the fresh flesh (KUMAH and OLYMPIO, 2011). Two fruits per replicate per treatment were randomly selected. The results were measured in (N) force unit.

Total soluble solid (TSS)

Total soluble solid (TSS) was measured by a digital refractometer device (model Milwaukee MA871) (°Brix). TSS was calculated for each fruit as an average of two readings of the digital refractometer, and the result was recorded as a degree °Brix (PILA et al., 2010). The refractometer was calibrated using distilled water before readings were taken.

Titratable acidity (TA)

Titratable acidity (TA) in tomato fruit juice samples was quantified by titration method using 0.1 mol L^{-1} NaOH, and the endpoint was pH (8.1). 15 ml of tomato juice were diluted with 85 ml of distilled water; 4 drops of phenolphthalein were added as an indicator for a color change to purple. The tomato fruit juice then titrated with 0.1 NaOH to pH (8.1) using the pH meter. The protocol was established by (GARNER et al., 2003) from UC Davis, California, USA. Used with modifications to estimate the titratable acidity in the sample.

The result was expressed as a citric acid percentage using the following formula:

$$\textit{Acid \%} = \frac{\text{(Mls NaOH used)}\cdot\text{(0.1 N NaOH)}\cdot\text{(Milliequivelent factor for tomato)}\cdot\text{(100)}}{\text{grams of sample}}$$

Mill equivalent factor = 0.0064 g

Statistical analysis

All statistical tests were performed using analysis of variance (ANOVA) using the SAS (SAS Institute Inc., 1998), Duncan multiple range test was used for evaluating mean separation at 5% level of probability, using sigma plot (version 8) in draw figure to show a significant difference.

Result and discussion

Weight loss

In general, fruit weight loss was normally attributed to fruits senescence or desiccation (NASRIN et al., 2008); it was also used as a quality index in the postharvest life of fruits. In this study, all samples showed a gradual loss of weight during storage, starting on day four of the experiment in both treated and non-treated fruits (Fig. 1, A). From day 8 until 16, no significant (P<0.05) differences were found between different coating treatments, except coating with 50% cactus mucilage. The control showed a significant (P<0.05) higher weight loss compared to all other coating treatments (Fig. 1, A). Furthermore, 6% $CaCl_2$ in-combination treatments of either arabic gum or cactus mucilage postharvest coating effectively reduced weight loss after 20 days up to the end of the storage period (Fig. 1, B). The results are in agreement with previous studies, which reported that weight loss was reduced with natural substance postharvest coating treatment such as arabic gum in tomato (ALI et al., 2013), combined coating of arabic gum, chitosan with pectin in mango (CHIEN et al., 2007). Furthermore, arabic gum alone or combined with calcium chloride on mango (KHALIQ et al., 2015). Meanwhile, GARCÍA et al. (2014) found coating with pure aqueous extract of *Aloe vera* did not delay the weight loss in tomato.

The loss of weight in fruits occurred during the transpiration process through the fruits' surface, which is a normal metabolic process resulting in shriveling and deterioration of the fruit, depends on the gradient of water vapor pressure 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 (arabic gum and cactus mucilage) and the $CaCl_2$. Where, combination treatments act as a barrier against O_2, CO_2, limiting water transfer and solute movement, therefore, reducing respiration, water loss and oxidation reaction rates (BALDWIN et al., 1999). Moreover, $CaCl_2$ treatments found to delay ripening and extended storage life (IRFAN et al., 2013), through reducing the concentration of O_2 and increasing the concentration of CO_2 in which help in delay senescence and ripening by reducing respiration and ethylene production rate in climacteric fruits as tomato fruits (PILA et al., 2010).

Fruit decay

During this study, the coating treatments had delayed decay symptoms of fruits upto 20 days post-treatment compared with 12 days in non-treated control. At 24 days of cold storage, fruit decay started in all coating treatments and gradually increased in all fruits with storage time, but not in fruits coated with 6% $CaCl_2$-treatments in-combination with 10% arabic gum (Fig. 2, A). Furthermore, the combination treatments of 6% $CaCl_2$-treatments in-combination with 10% arabic gum or combination with 50% cactus mucilage showed the lower significant (p<0.05) decayed fruits compared to the alone treatment of each of 6% $CaCl_2$, 10% arabic gum and 50% cactus mucilage postharvest treatments at day 28, and at the termination day of the experiment (day 35) (Fig. 2, B).

Fruit decay is a natural phenomenon associated with the ripening process and postharvest diseases (KHALIQ et al., 2015). The current results clearly indicate a significant role of coating substance and calcium chloride combined treatments in reducing fruit decay. Calcium chloride plays a major role in strengthening and thickening the middle lamella of the cell wall, through increased formation and deposition of Ca-pectate in the cell wall (GARCIA and HERRERA, 1996).

During fruit ripening under long-term storage, fungi and bacteria were associated with some enzymatic change processes, which trigger damage to fruits and deteriorate the middle lamella, in particular plant enzymes associated with the senescence process (ZAPATA et al., 2008).

The current results agreed with SHARMA et al. (1996), who reported dipping apple fruits in calcium chloride reduced postharvest decay and delayed senescence compared to non-treated fruits. In addition, KHALIQ et al. (2015) reported, coating mango fruits with arabic gum protected the fruits from pathogen infection and suggested coating forms a film on the mango surface. This film acts as a barrier to protect the fruits.

Fruit color development

Tomato fruit color is an important factor in determining fruit quality. Additionally, it is the first sensory parameter for acceptance by consumers (NASRIN et al., 2008). Our results indicate a normal pattern of color development in non-treated and treated tomato fruits (Fig. 3, A). A significant (P<0.05) development of the red color occurred after 8 days in control (non-treated) fruits compared to other different treated fruits. The 'a' value is changed from a negative value (green color) to a positive value (red color) (Fig. 3, B). No significant changes in color development were observed in other treatments as fruits were still predominately at the mature breaker stage (pink to light red). During the first 8 days, no significant changes were observed in 'L' and 'b' values among the treatments. The 'L' parameter is a sign of fruit from light to dark; all samples showed decrease 'L' values with progressing the storage times. Coating substance significantly reserved 'L' value compared with control (non-treated) fruits. However, no significant differences were observed among the other treatment at day 35 of storage (Fig. 3, A). The 'b' value also decreased with increasing the storage time in all fruits (Fig. 3, C). Coating treatments significantly (P<0.05) delayed color development of tomato fruits.

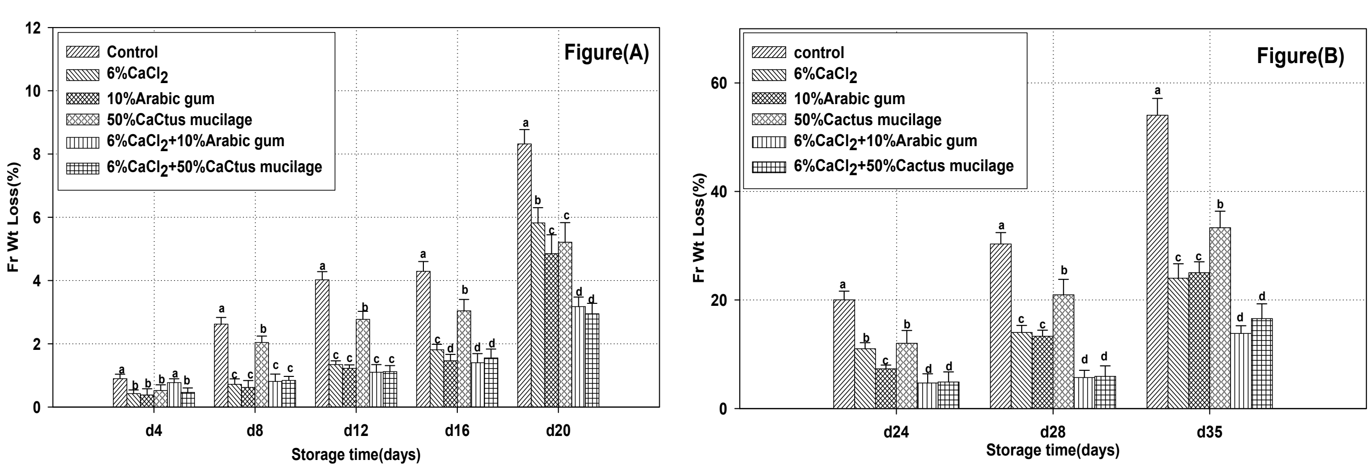

Fig. 1 (A, B): Effect of natural substance postharvest combination treatments with $CaCl_2$ on the fruit weight loss of tomato fruits at cold storage. Means followed by the same letter are not significantly different (Duncan's multiple range test, P > 0.05)

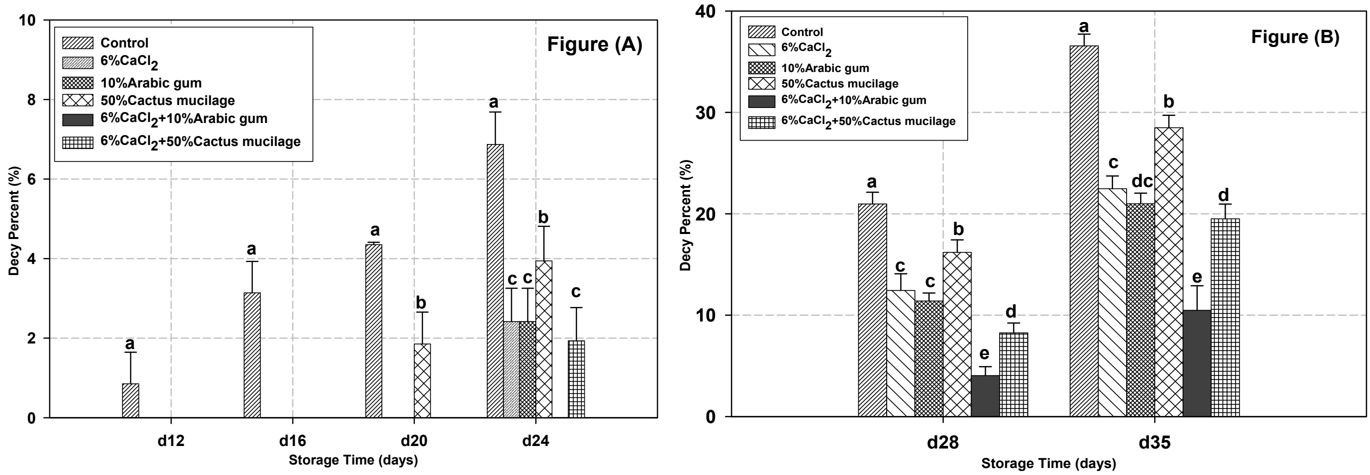

Fig. 2 (A, B): Effect of natural substance combination with CaCl2 on decay tomatoes fruit during cold storage at (10 °C). Means followed by the same letter are not significantly different (Duncan's multiple range test, P > 0.05)

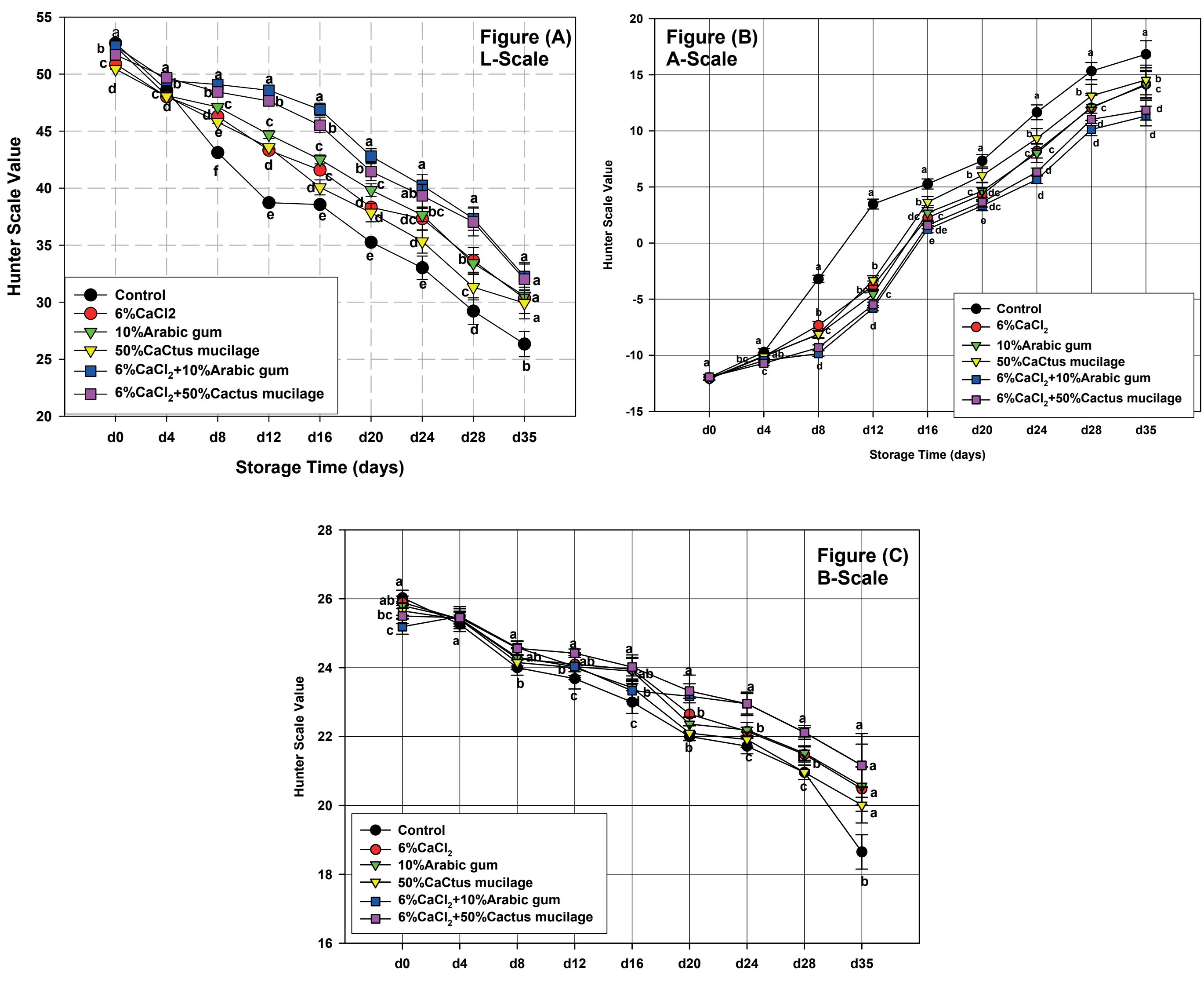

Fig. 3 (A, B, C): Effect of natural substance combination with $CaCl_2$ on the color development of tomatoes fruit stored at cold storage (10 °C). Means followed by the same letter are not significantly different (Duncan's multiple range test, P > 0.05)

The number of days required for treated tomato fruits to develop color from pink to full red was up to 16 days from harvest, compared to 8 days in control (non-treated) fruits (Fig. 3, B). A clear positive influence of postharvest coating by 6% $CaCl_2$-treatments in-combination with 10% arabic gum on delaying fruit ripening, as treated fruits required more time to develop red color (16 days), compared to other treatments which developed the red color stage in 12 days (Fig. 3 A, B and C).

Color development in ripe tomato resulted of the de-novo synthesis of carotenoids, mainly lycopene and β-carotene associated with the change in fruit color from green to red as chloroplasts are transformed to chromoplasts (Bathgate et al., 1986). Coating substance was found to delay chlorophyll degradation and lycopene synthesis, as well as ripening processes compared to uncoated fruits (Yaman and Bayoindirli, 2002). However, this delayed fruit color development could be attributed to the modified fruits surrounding atmosphere; reduced O_2 concentration and increased CO_2 concentration. This reduces the respiration and ethylene production rate in climacteric fruits (Pila et al., 2010) and, therefore, helps in delay ripening and the associated changes in fruit color development. It was reported that arabic gum coatings delayed colour changes in tomato (Ali et al., 2010; Al-Juhaimi, 2012) and guava (Gurjar et al., 2018), while calcium chloride delayed colour in fig fruits (Irfan et al., 2013). Barman et al. (2011) reported that combined application of putrescine and carnauba wax reduced colour changes and preserved pomegranate quality during storage. In this study, the delay in color changes in tomato fruits treated with 6% $CaCl_2$-treatments combined with 10% arabic gum might have been resulted from decreased biosynthesis of carotenoids and preservation of chlorophyll content.

Firmness

Tomato fruits' coating by different natural substance (10% arabic gum and 50% cactus mucilage) in addition to 6% $CaCl_2$-treatments showed a positive significant ($P<0.05$) effect on fruits firmness compared to control (non-treated) fruits (Fig. 4 A and B). During the time course of the experiments, high significant ($P<0.05$) values were found in 6% $CaCl_2$-treatment in-combination with 10% arabic gum, or 50% cactus mucilage compared to other solo coating treatments and control. Therefore, the in-combination treatments preserved tomatoes fruits' firmness compared to other treatments (Fig. 4 A and B).

Fruit texture is an important characteristic of fresh horticulture produce. The current results indicted non-treated fruits are softening and lost textural quality rapidly compared to treated fruits. These changes are attributed to deterioration in cell structure, cell wall composition and intracellular components during the ripening process under storage conditions (Harold et al., 2007) as it had been reported for a wide range of fruits, including tomato (Ruelas-Chacon et al., 2017), mango (Khaliq et al., 2015; Chien et al., 2007) and plums (Valer 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 cell wall activity degrading enzymes, so the outer membrane for the cell wall becomes more strength and rigid (Khaliq et al., 2015; Pila et al., 2010). Coating substances (arabic gum and cactus mucilage) in-combination treatments also helped create a modified atmosphere surrounding the fruit's surface. Whereas elevating the CO_2 and decreased the fruit respiration rate (Ali et al., 2013), therefore limit the activity of softening related biochemical enzymes activity such as; hydrolases, pectin esterase, and polygalacturonase (Arah et al., 2016; Ruelas-Chacon et al., 2017). Therefore, the in-combination treatments of $CaCl_2$ and coating substances retained significantly ($P\leq0.05$) a higher firmness over the control fruits may be attributed to the thick coating, which created a modified atmosphere around the fruit surface, as a result, reduced changes in pectin substances and activity of cell wall degrading enzymes (Khaliq et al., 2015) in addition to the role of Calcium in preserve cell wall structure by interacting with pectin in the cell wall to form calcium pectate complexes and reduce the activity of cell wall degrading enzymes.

Total soluble solid (°Brix)

In general, there was a gradual increase in total soluble solid (TSS) during the entire storage period (Fig. 5). No significant difference ($p<0.05$) was observed between control (non-treated) fruits and different postharvest coating treatments from zero days (harvest day) until 12 days at cold storage (Fig. 5 A). While, after 16 days of storage up to the termination day of the experiments (day 35[th]), a higher significant ($p<0.05$) difference in total soluble solid was found in control (non-treated) fruits compared to 6% $CaCl_2$-treatments in-combination with 10% arabic gum or 50% cactus mucilage coating treatments (Fig. 5 B).

Fruit soluble solid concentration is a good index for determining fruit quality and maturity; it increases with maturity and ripening. Changes in the soluble solids content of tomatoes are correlated

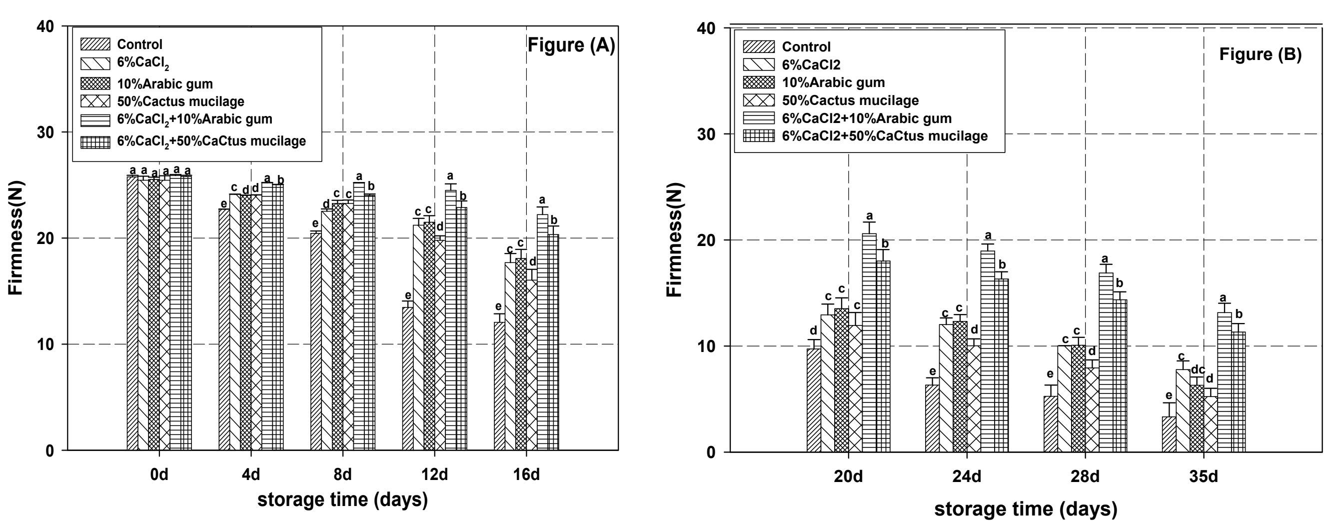

Fig. 4 (A, B): Effect of natural substance combination with $CaCl_2$ on the firmness (N) of tomato fruits at cold storage (10 °C). Means followed by the same letter are not significantly different (Duncan's multiple range test, $P > 0.05$)

with hydrolytic changes in polysaccharides (hemicellulose and pectin) during ripening (Ruelas-Chacon et al., 2017). A similar to the presented TSS change pattern was found in tomato fruits coated with arabic gum (Ali et al., 2010; Al-Juhaimi, 2012), or with Aloe vera (García et al., 2014) and mango fruits coated with arabic gum combined with calcium chloride (Khaliq et al., 2015). Coating with natural substances can reduce the respiration rate and may slow down the synthesis and use of metabolites resulting in lower TSS (Ali et al., 2013) that may explain the higher concentration of TSS in non-treated fruits.

Titratable Acidity (TA)

Titratable acidity (TA) is the most essential parameter for evaluating fruits quality during storage. Lower values in TA concentration in fruits; faster fruit induced senescence (Khaliq et al., 2015). In this study, TA values of coated and non-coated fruit during storage decreased with storage time (Fig. 6). After 12 days of storage until the termination day of the experiments (day 35^{th}), the total soluble solid values were significantly higher ($P \leq 0.05$) in 6% $CaCl_2$-treatments in-combination with 10% arabic gum or with 50% cactus mucilage coating treatments compared to other coating treatments and control (non-treated) fruits (Fig. 6 A). While after 20 days a significantly ($P \leq 0.05$) higher value was found in 6% $CaCl_2$ treatments of, coating with either 10% arabic gum or 50% cactus mucilage compared to control (non-treated) fruits (Fig. 6 B). Titratable acidity decreased progressively with fruit ripening, and the decline rate significantly affected by the coating treatments with 10% arabic gum or with 50% cactus mucilage coating combined with 6% $CaCl_2$. The significant lower level of TA in control fruit compared to coated fruit suggested that, coating delayed ripening by providing modified atmosphere around fruit surface and creating a barrier against O_2 and CO_2, led to reduce respiration rate (Rodriguez et al., 2006; Ali et al., 2010). Preservation of titratable acidity by fruit coating treatments has been reported previously for various fruits as tomato coated with arabic gum (Ali et al., 2010; Al-Juhaimi, 2012) or with *Aloe vera* (García et al., 2014) and mango fruits coated with arabic gum combined with calcium chloride (Khaliq et al., 2015).

Conclusion

This study indicated that coating tomato fruits with either 10% arabic gum or 50% cactus mucilage combined with pre-dipping in 6% $CaCl_2$ positively affect the physical and chemical properties of

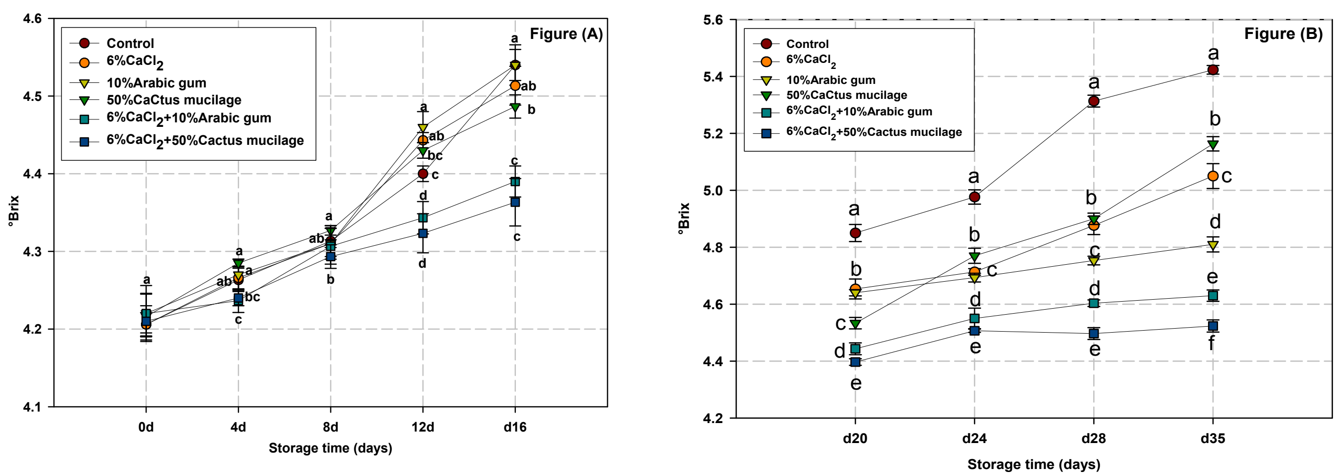

Fig. 5 (A, B): Effect of natural substance combination with $CaCl_2$ on the total soluble solid (°Brix) of tomato fruits at cold storage (10 °C). Means followed by the same letter are not significantly different (Duncan's multiple range test, $P > 0.05$)

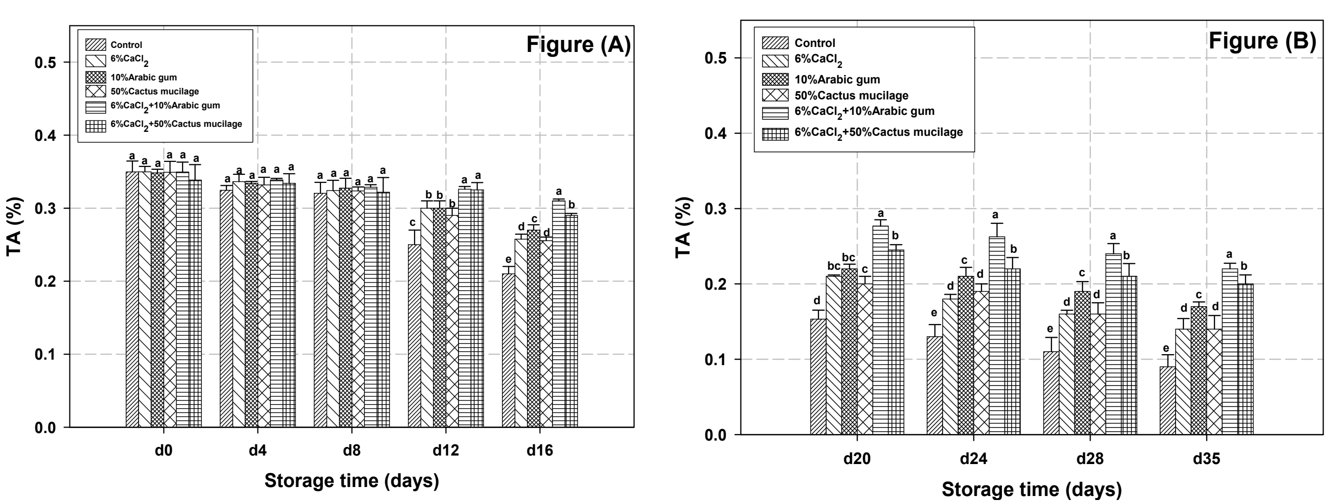

Fig. 6 (A, B): Effect of natural substance combination with $CaCl_2$ on the titratable acid of tomatoes fruit at cold storage (10 °C). Means followed by the same letter are not significantly different (Duncan's multiple range test, $P > 0.05$)

tomato fruits, thus maintaineing the overall quality of fruits. A significant delay in fruit weight loss, firmness, titratable acidity, soluble solids concentration and color development was found during storage at 10 ± 1 °C compared to uncoated control fruit. Further research is needed to investigate the influence of the coating on ripening physiological processes, postharvest microbes inhibition, and on tomato fruit quality attributes under ambient storage conditions.

Acknowledgments
This research was supported by An-Najah National University. The authors gratefully acknowledges the excellent technical assistance by the team of the National Agricultural Researcher Center (NARC), Ministry of Agriculture, Qabatya, Palestine.

Conflict of interest
No potential conflict of interest was reported by the authors.

Reference

Abbasi, N.A., Zafar, L., Khan, H.A., Qureshi, A.A., 2013: Effects of naphthalene acetic acid and calcium chloride application on nutrient uptake, growth, yield and postharvest performance of peach fruit. Pak. J. Bot. 45(5), 1581-1587.

Adato, A., Mandel, T., Mintz, S., Venger, I., Levy, D., Yativ, M., Domínguez, E., Wang, Z., Vos, R., Jetter, R., Schreiber, L., Heredia, A., Rogachev, I., Aharoni, A., 2009: Fruit-surface flavonoid accumulation in tomato is controlled by a SlMYB12-regulated transcriptional network. PLos Genetics. 5(12), e1000777. DOI: 10.1371/journal.pgen.1000777

Ali, A., Maqbool, M., Alderson, P., Zahid, N., 2013: Effect of gum arabic as an edible coating on antioxidant capacity of tomato (*Solanum lycopersicum* L.) fruit during storage. Postharvest Biol. Tec. 76, 119-124. DOI: 10.1016/j.postharvbio.2012.09.011

Ali, A., Maqbool, M., Ramachandran, S., Alderson, P.G., 2010: Gum arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (*Solanum lycopersicum* L.) fruit. Postharvest Biol. Tec. 58(1), 42-47. DOI: 10.1016/j.postharvbio.2010.05.005

Al-Juhaimi, F.Y., 2012: Physicochemical and Sensory Characteristics of Arabic Gum-Coated Tomato (*Solanum Lycopersicum* L.) Fruits during Storage. J. Food Proc. Pres. 38(3), 971-979. DOI: 10.1111/jfpp.12053

Arah, I.K., Ahorbo, G.K., Anku Kumah, E.K., Amaglo, H., 2016: A review. Postharvest handling practices and treatment methods for tomato handlers in developing countries. Postharvest Hand. Tec. 1-8. DOI: 10.1155/2016/6436945

Baldwin, E.A., Scott, J.W., Shewmaker, C.K., Schuch, W., 2000: Flavor trivia and tomato aroma: biochemistry and possible mechanisms for control of important aroma components. Hort. Sci. 35(6), 1013-1022. DOI: 10.21273/hortsci.35.6.1013

Baldwin, E.A., Burns, J.K., Kazokas, W., Brecht, J.K., Hagenmaier, R.D., 1999: Effect of two edible coatings with different permeability characteristics on mango (*Mangifera indica* L.) ripening during storage. Postharvest Biol. Tec. 17(3), 215-226. DOI: 10.1016/S0925-5214(99)00053-8

Bathgate, B., Goodenough, P.W., Grierson, D., 1986: Regulation of the expression of the gene in tomato fruit chloroplasts and chromoplasts. J. Plant Physiol. 124(3-4), 223-233. DOI: 10.1016/S0176-1617(86)80036-0

Barman, K., Asrey, R., Palr, R.K., Kaur, C., Jha, S.K., 2011: Influence of putrescine and carnauba wax on functional and sensory quality of pomegranate (*Punica granatum* L.) fruits during storage. J. Food Sci. Technol. 51(1), 111-117. DOI: 10.1007/s13197-011-0483-0

Borguini, R., Torres, E., 2009: Tomatoes and tomato products as dietary sources of antioxidants. Food Rev. Intern. 25, 313-325. DOI: 10.1080/87559120903155859

Chien, P.J., Sheu, F., Yang, F.H., 2007: Effects of edible chitosan coating on quality and shelf life of sliced mango fruit. J. Food Eng. 78(1), 225-229. DOI: 10.1016/j.jfoodeng.2005.09.022

Del-Valle, V., Hernández-Muñoz, P., Guarda, A., Galotto, M.J., 2005: Development of a cactus-mucilage edible coating (*Opuntia ficus-indica*) and its application to extend strawberry (*Fragaria ananassa*) shelf-life. J. Food Chem. 91, 751-756. DOI: 10.1016/j.foodchem.2004.07.002

Dhall, R.K., 2013: Advances in edible coatings for fresh fruits and vegetables: A Review. Crit. Rev. Food Sci. Nut. 53(5), 435-450. DOI: 10.1080/10408398.2010.541568

El-Anany, A.M., Hassan, G.F.A., Rehab Ali, F.M., 2009: Effects of edible coatings on the shelf – life and quality of an apple (*Malus domestica* Borkh) during cold storage. J. Food Tech. 7, 5-11.

Gao, Q., Tan, Q., Song, Z., Chen, W., Li, X., Zhu, X., 2020: Calcium chloride postharvest treatment delays the ripening and softening of papaya fruit. J. Food Proc. Pres. 44(8). DOI: 10.1111/jfpp.14604

Garcia, J.M.S., Herrera, A., 1996: Effect of postharvest dip in calcium chloride on strawberry. J. Agric. Food Chem. 44, 30-33. DOI: 10.1021/jf950334l

García, M.A., Ventosa, M., Díaz, R., Falco, S., Casariego, A., 2014: Effects of aloe vera coating on postharvest quality of tomato. J. Fruits, Sci. Tec. 69(2), 117-126. DOI: 10.1051/fruits/2014001

Garner, D., Crisosto, C.H., Wiley, P., Crisosto, G.M., 2003: Measurement of pH and Titratable Acidity. Retrieved 3rd February 2020, from http://fruitandnuteducation.ucdavis.edu/files/162035.pdf

Gheribi, R., Khwaldia, K., 2019: Cactus mucilage for food packaging applications. Coatings 9(10), 655. DOI: 10.3390/coatings9100655

Gurjar, P.S., Killadi, B., Lenka, J., Shukla, D.K., 2018: Effect of gum arabic coatings on physico-chemical and sensory qualities of guava (*Psidium guajava* L) cv. Intern. J. Current Microbiol. Sci. 7(4), 3769-3775. DOI: 10.20546/ijcmas.2018.704.424

Harold, C.P., Karapanos, I.C., Bebeli, P.J., Savvas, D., 2007: A review of recent research on tomato nutrition, breeding and postharvest technology with reference to fruit quality. J. Plant Sci. Bio. 1(1), 1-21.

Hernalsteens, S., 2020: Edible films and coatings made up of fruits and vegetables. In: Biopol. Mem. Films, 575-588. DOI: 10.1016/b978-0-12-818134-8.00024-9

Irfan, B.K., Vanjakshi, V., Keshava, M.N., Prakasha, R., Ravi Kudachikar, V.B., 2013: Calcium chloride extends the keeping quality of fig fruit (*Ficus carica* L.) during storage and shelf-life. Postharvest. Biol. Tec. 82, 70-75. DOI: 10.1016/j.postharvbio.2013.02.008

Kashif, G., Fahad, Y., 2013: Effects of Gum arabic coating on physico chemical properties and kinetics of color change in strawberry. J. Food Agric. Env. 11(2), 142-148.

Kapsiya, J., Gungula, D.T., Tame, V.T., Bukar, N., 2015: Effects of storage chemicals and packaging systems on physicochemical characteristics of tomato (*Solanum lycopersicum* L.) fruits. AASCIT. J. Biosci. 1(3), 41-46.

Khaliq, G., Mohamed, M.T., Ali, A., Ding, P., Ghazali, H.M., 2015: Effect of gum arabic coating combined with calcium chloride on physico-chemical and qualitative properties of mango (*Mangifera indica* L.) fruit during low temperature storage. J. Sci. Hort. 190, 187-194. DOI: 10.1016/j.scienta.2015.04.020

Kumah, P., Olympio, N., 2011: Sensitivity of three tomato (*Lycopersicon esculentum*) cultivars – Akoma, Pectomech and power – to chilling injury. Agri. Biol. J. North America. 2(5), 799-805. DOI: 10.5251/abjna.2011.2.5.799.805

Mehmet, U.K., Rezzan, K., 2016: The effects of calcium chloride and ascorbic acid treatment on ready-to-use carrot shreds. J. Life. Sci. 10(1). DOI: 10.17265/1934-7391/2016.01.002

Nasrin, T., Molla, M., Hossaen, M.A., Alam, M., Yasmin, L., 2008: Effect of postharvest treatments on shelf life and quality of tomato. J. Agric. Res. 33(4), 579-585. DOI: 10.3329/bjar.v33i4.2291

Pila, N., Gol, N.B., Rao, T.V.R., 2010: Effect of postharvest treatments on physicochemical characteristics and shelf life of tomato (*Lycopersicon* *esculentum* Mill.) fruits during storage. American Eurasian J. Agric. Env. Sci. 9(5), 470-479.

RODRIGUEZ, M., OSES, J., ZIANI, K., MATE, J.I., 2006: Combined effect of plasticizers and surfactants on the physical properties of starch based edible films. Food Rese. Intern. 39, 840-846. DOI: 10.1016/j.foodres.2006.04.002

RUELAS-CHACON, X., CONTRERAS-ESQUIVEL, J.C., MONTAÑEZ, J., AGUILERA-CARBO, A.F., REYES-VEGA, M.L., PERALTA-RODRIGUEZ, R.D., SANCHÉZ-BRAMBILA, G., 2017: Guar gum as an edible coating for enhancing shelf-life and improving postharvest quality of roma tomato (*Solanum lycopersicum* L.). J. Food Qual. 1-9. DOI: 10.1155/2017/8608304

SAS INSTITUTE, 1998: SAS Users Guide, Statistics. Version 2. SAS Institute, Cary, NC.

SENEVIRATHNA, P., DAUNDASEKERA, W., 2010: Effect of postharvest calcium chloride vacuum infiltration on the shelf life and quality of tomato (cv. 'Thilina'). Ceylon. J. Sci. Biol. 39(1), 35. DOI: 10.4038/cjsbs.v39i1.2351

SHARMA, R.M., YAMDAGNI, R., GAUR, H., SHUKLA, R.K., 1996: Role of calcium in horticulture. A review. Haryana J. Hort. Sci. 25(4), 205.

VALERO, D., DIAZ-MULA, H.M., ZAPATA, P.J., GUILLEN, F., MARTÍNEZ-ROMERO, D., CASTILLO, S., SERRANO, M., 2013: Effect of alginate edible coating on preserving fruit quality in four plum cultivars during postharvest storage. Postharvest Biol. Tec. 77, 1-6. DOI: 10.1016/j.postharvbio.2012.10.011

VOSS, DH., 1992: Relating colorimetric measurement of plant color to the Royal Horticultural Society Color Chart. Hort. Sci. 27, 1256-1260. DOI: 10.21273/HORTSCI.27.12.1256

YAMAN, O., BAYOINDIRLI, L., 2002: Effects of an edible coating and cold storage on shelf-life and quality of cherries. J. Food Sci. Tec. 35(2), 146-150. DOI: 10.1006/fstl.2001.0827

ZAPATA, P.J., GUILLÉN, F., MARTÍNEZ-ROMERO, D., CASTILLO, S., VALERO, D., SERRANO, M., 2008: Use of alginate or zein as edible coatings to delay postharvest ripening process and to maintain tomato (*Solanum lycopersicon* Mill) quality. J. Sci. Food Agric. 88(7), 1287-1293. DOI: 10.1002/jsfa.3220

ZEGBE, J.A., MENA-COVARRUBIAS. J., DOMÍNGUEZ-CANALES, V.S.I., 2015: Cactus mucilage as a coating film to enhance shelf life of unprocessed guavas (*Psidium guajava* L). Acta Hort. (1067), 423-427. DOI: 10.17660/ActaHortic.2015.1067.58

ORCID
Tawfiq Qubbaj https://orcid.org/0000-0003-2258-1371

Address of the corresponding author:
Tawfiq Qubbaj, Department of Plant Production and Protection, Faculty of Agriculture and Veterinary Medicine, An-Najah National University, P.O. Box 7, Nablus, Palestine
E-mail: tqubbaj@najah.edu