J. Agric. Sci. Technol. (2023) Vol. 25(4): 963-974

Postharvest Guar Gum Coating Modulates Fruit Ripening, Storage Life, and Quality of Tomato Fruits Kept in Ambient or Cold Storage Conditions

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ABSTRACT

The growing interest in natural edible coatings to substitute commercial waxing would preserve agricultural products' postharvest quality. Tomato fruits' physical and chemical changes were investigated post-coating with 1.5% guar gum, then stored at room temperature or cold storage conditions. Tomato fruits at "breaker stage" were soaked in a 1.5% guar gum solution for 1 minute and then stored at room temperature (21°C, RH 45%) or cold storage (10°C, RH 85%). Results showed that guar gum coating significantly (P≤ 0.05) preserved fruit firmness and organoleptic quality attributes. The fruit weight loss, decay percentage, Titratable Acidity (TA), Total Soluble Solids (TSS), and fruit color development were significantly preserved in guar gum-coated fruits compared to non-coated fruits. Guar gum could maintain the quality of tomato fruit combined with low temperature for 35 days. Moreover, fruits coated with 1.5% guar gum kept at room temperature preserved the quality of fruits as uncoated fruits stored at cold temperatures. Therefore, guar gum could be an alternative to cold storage, as it is environmentally friendly and more economical than cold storage, especially in developing countries.

Keywords: Climacteric fruit ripening, Coating substance, Fruit decay, Fruits edible coating, *Solanum lycopersicum* L.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops cultivated globally due to its health and economic importance (Abdelgawad *et al*., 2019). Tomato fruits have considerable nutritional value; they contain lycopene, carotenoids, vitamin C, and minerals that play an essential role in preventing the development of some human diseases such as prostate and breast cancer (Ali *et al*., 2020). Tomato is climacteric fruit, and its quality declines rapidly after harvest due to the soft texture and susceptibility to microbial infections (Said *et al*., 2021). Generally, the quality of climacteric fruits is highly affected by postharvest conditions such as transportation and storage during ripening (Al-Dairi *et al*., 2021). Several biochemical processes occur during fruit ripening, such as pectin degradation, cell wall degradation, membrane degradation, reduction in acidity with a breakdown of stored carbohydrates into sugars, and increased biosynthesis of color volatile aroma components; all of which contribute to an overall improvement in fruit quality attributes (Drobek *et al*., 2020). Climacteric fruit ripening is controlled by several postharvest methods to reduce the respiration rate and ethylene synthesis. Fruits coated with various natural substances reduce fruit decay and weight loss by forming a semi-permeable film on

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the fruit, enhancing the waxy cuticle, and reducing water loss (Kocira *et al*., 2021). Guar gum is a galactomannan polysaccharide extracted from the Indian legume cluster bean *Cyamopsis tetragonoloba* (*L.*) Taub. It is used as a thickener and stabilizer for many food applications, delays ripening, extends shelf life, and reduces the browning of fruits caused by molds (Thombare *et al*., 2016). Guar gum has been used as a coating agent on some fruits and vegetables. It is readily available, inexpensive, and biodegradable, delays ripening, maintains firmness, and extends shelf life for Roma tomato under room temperature storage conditions (Ruelas-Chacon *et al*., 2017), mango fruits at cold storage (Hmmam *et al*., 2021), red chili pepper (Minh *et al*., 2019), and cucumber (Saha *et al*., 2016). Ziv and Fallik (2021) reported that using guar gum as a coating agent positively affects fruit quality and prolongs shelf life by controlling the ripening, respiration, weight loss, and maintaining the firmness and texture of fruit during storage. Very few to no studies have been reported on the interaction of guar gum as a coating substance and different storage temperatures. Therefore, this study aimed to investigate the potential interaction effects of guar gum as a coating agent on fruit ripening, storage life, and quality of tomato fruits kept in ambient or cold storage conditions.

MATERIALS AND METHODS

Fruit Material

Tomato Izmir fruit harvested at the breaker ripening stage were immediately transported to the postharvest laboratory at the National Agriculture Research Center (NARC). Fruits with uniform size, color, free from bruises and defects, were selected for further treatments.

Postharvest Treatment

Coating Substance

The 1.5% guar gum coating solution was prepared by dissolving 1.5 g guar gum powder (Sigma-Aldrich St. Louis, MO, USA) in 100 mL distilled water. The solution was heated to 60 °C for 30 minutes using a magnetic starrier (model SP 18420-26 Barnstead Thermolyne USA) and then cooled to 21°C for 60 minutes. Three hundred sixty tomato fruits were randomly divided into four sets of 90 fruits each. The first set was coated with 1.5% guar gum for 1 minute and then stored at cold temperature. The second set was coated with 1.5% and then stored at room temperature. Two control sets were also run alongside; fruits were dipped in distilled water for 1 minute, and then one set was stored at room temperature and the other in cold storage

Analysis of Quality Parameters

Fruit quality attributes (% Weight loss, % Decay fruits, Firmness (N), Fruit color development, Brix, TA, and Ripening index) were evaluated before treatment (day-0), then, every four-days intervals, at both storage temperatures (21°C) and under cold storage (10 °C) with Relative Humidity (RH) of 45 and 85%, respectively.

Weight Loss

Six fruits for each treatment were weighed at zero-day and every four days, using a digital balance (Analytical Digital Balance Single Pan). Weight loss was calculated as a percentage using the following formula (Sati and Qubbaj, 2021):

% Weight loss= [(Initial weight-Final weight)/Initial weight))]×100

Fruit Decay

The decay of the fruit was determined visually. Fruit decay and skin spots were monitored, and the decay percentage was recorded using the following formula (Sati and Qubbaj, 2021) for both treated and untreated fruits:

$$\% \text{ Fruit decay} = (\frac{decay\ fruit}{initial\ fruit}) * 100.$$

Fruit Color Development

The color development of tomato fruits was evaluated using a chroma meter (KONICA MINOLTA) following (Sati and Qubbaj, 2021). The average values of two measurements per fruit from each side were recorded for measuring L (brightness), ɑ (red or green), b (yellow or blue), hue angle (expresses the color changes of the tomato), and chroma index (analyzes the color value of the tomato).

Firmness Measurements (N)

For each treatment, two fruits per replicate were used to measure firmness using a digital penetrometer (Lutron FR -5120, QA Supplies LLC, Norfolk, VA, USA) using a 6 mm diameter tip following Sati and Qubbaj (2021). Results were expressed in Newton.

Total Soluble Solid (°Brix)

For each treatment, two fruits per replicate were measured using a digital refractometer (Milwaukee MA871-model, Milwaukee Instruments Inc., Rocky Mount, NC, USA), and results were expressed as a degree scale - °Brix.

Titratable Acidity (TA)

Fifteen mL of tomato fruit juice was diluted with 85 mL of distilled water and then titrated with 0.1 N NaOH, using phenolphthalein as an indicator, changing color from pink to purple (Sati and Qubbaj, 2021). The result was expressed as a percentage of citric acid using the following formula:

% Acidity= [(Titration value×Normality×Milli equivalent)/(Volume of sample)]×100.

Millequivalent factor= 0.0064 g.

Ripening Index

The ripening index was calculated as the ratio of measured total soluble solid to titratable acidity of tomato juice as described by Sati and Qubbaj (2021) using the following formula:

Ripening index= Measured TSS/Measured TA.

Statistical Analysis

A factorial experiment based on a completely randomized design with three factors (guar gum coating, storage temperature, and storage time) was used, with three replicates per treatment. Every replicate consisted of 90 fruits. ANOVA test was used at P≤ 0.05 by the SAS statistical software (Analytical Software., 2010), then, Student–Newman–Keuls (SNK) range test was used to separate between the mean values.

RESULTS AND DISCUSSION

Effect of Guar Gum and Storage Temperature on Tomato Fruits

The result showed that coating fruits with 1.5% guar gum and storage at 21 or 10°C positively impacts the physico-chemical properties of tomato fruits compared with uncoated fruits (control). The interaction effect of storage temperature with 1.5% guar gum coating showed a significant effect on prolonging the storage life and preserving quality during the postharvest life of tomato fruits compared with uncoated fruits (Table 1). Uncoated fruits (control) had a short storage life, up to 24 days at 10°C, and 12 days at 21°C, while coated fruits were preserved up to 35 days at cold storage and up to 20 days at room temperature.

Weight Loss

The result showed that fruits coated with 1.5% guar gum had a significantly ($P \leq 0.05$) reduced weight loss rate in comparison to uncoated fruits at both storage temperatures (Figure 1). Besides, the interaction effects of storage time, temperature, and guar gum coating were significant in fruit weight loss (Table 1). The low storage temperature combined with 1.5% guar gum coating significantly reduced the tomato fruits weight loss over the period of 35 days storage time. Also, 11.3% weight loss was recorded for coated fruits stored at 10°C for 35 days, whereas 30% weight loss was recorded for non-coated fruits stored at 10°C for 24 days. Also, the 1.5% guar gum coating combined with room temperature storage significantly preserved fruit weight, and this effect was not significantly different when uncoated fruits were kept at low storage temperature (Figure 1). Therefore, the guar gum coating has the same effects on fruit weight loss as cold storage effects, up to 20 days of storage.

The weight loss is usually attributed to fruit senescence or desiccation (Ali *et al*., 2021) during ambient storage. It has also been used as a quality index for postharvest fruit life. In this study, a reduced weight loss rate was observed due to guar gum application as an edible coating. Our finding agreed with previous studies on Roma tomato fruit coated with guar gum, kept at room temperature (Ruelas-Chacon *et al*., 2017) and tomato coated with Arabic gum (Sati and Qubbaj, 2021). Fruits coating was found to act as a semi-permeable layer that allows specific small molecules to pass

Table 1. Variance analysis of the effect of guar gum coating and storage temperature on quality attributes of tomato fruits.

SOV	df	Mean Square (MS)										
		Weight loss	Fruit decay	Firmness	Fruit Color Development					TA	TSS	Ripening index
					a-scale	L-scale	b-scale	Hue	Chroma			
Temperature (T)	1	46734.5*	3588.11*	852.779*	218.197*	2120.3*	1431.7*	9247.9*	1720.3*	0.1800*	34.998*	346.86*
Coating (C)	1	10128.3*	9578.68*	699.519*	214.123*	929.74*	519.34*	5002.7*	713.95*	0.0930*	9.6601*	12.150*
Storage time (D)	8	22971.0*	1907.94*	864.420*	424.372*	2179.9*	844.41*	7839.4*	1035.3*	0.1400*	26.432*	419.40*
T × C	1	2711.3*	1876.30*	14.040*	0.016^{ns}	17.14*	42.95*	136.80*	30.83*	0.0054*	0.8043*	26.156*
T × D	8	5687.7*	4664.97*	23.380*	48.942*	201.68*	217.66*	462.31*	186.87*	0.0117*	9.9159*	349.91*
C × D	8	1282.0*	475.65*	15.095*	28.617*	88.01*	101.25*	255.84*	90.80*	0.0056*	4.6594*	193.48*
T × C × D	8	2001.8*	1241.71*	31.627*	25.869*	173.51*	154.56*	427.51*	154.35*	0.0087*	6.6141*	222.84*
ERROR	70	4.6	32.08	0.560	0.371	0.67	0.03	2.01	0.09	0.0001	0.0065	4.622
C.V (%)		6.73	26.42	5.85	-14.57	3.40	0.98	3.25	1.54	6.41	2.36	15.33

^{ns} Not significant, and * Significant at 5% levels.

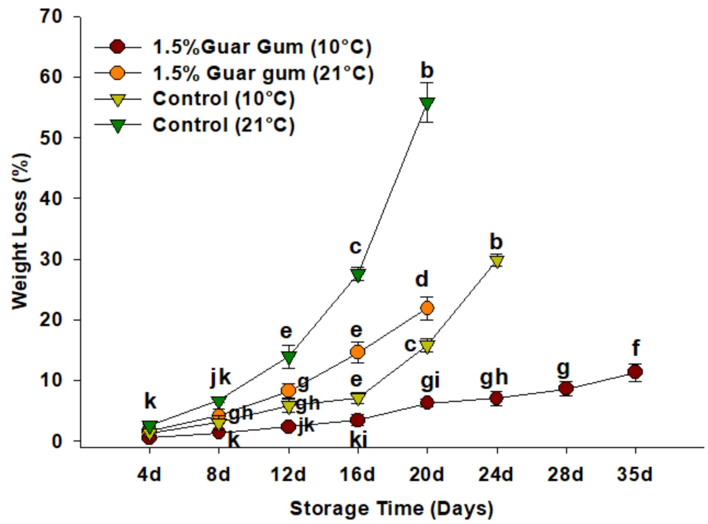

Figure 1. Impact of the coating substance guar gum on weight losses of tomato fruits during low (10 °C) and room temperature (21°C) storage. Means followed by the same letters are not significantly different at P≤ 0.05 (SNK test). Each value consisted of three biological replicates ±standard division.

through. It also serves as a protective barrier to reduce respiration and transpiration on fruit surface by forming a physical barrier to O_2, CO_2, moisture, and solute movement, thereby reducing water loss (Sultan *et al*., 2021).

Fruit Decay

The natural fruit decay phenomenon is related to ripening and storage conditions (Maduwanthi and Marapana, 2019). In this study, the 1.5% guar gum coating significantly (P≤ 0.05) reduced decay percent compared with uncoated fruits at each storage condition (Figure 2). The low temperature (10°C) storage condition combined with guar gum coating tended to maintain significantly (P≤ 0.05) lower decaying rates and delay the decay incident than the control during the storage. Fruits coated with guar gum (1.5%) and kept at 10°C had no decay symptoms until 16 days of storage. However, tomato fruits coated by the guar gum and stored at room temperature showed non-significant fruit decaying rates compared to uncoated fruits (control) stored at 10°C (Figure 2). Therefore, the guar gum coating has the same effects on reducing fruit decay as cold storage (10°C) effects, up to 20 days of storage. The untreated fruits stored at 21°C were totally un-marketable after 20 days of storage, so, they were not suitable for continuing the experiment.

Various microorganisms attack tomato fruits during the ripening process and under storage, such as bacteria and molds associated with some enzymatic alteration processes (Aboutalebi *et al*., 2014); damaging the fruits and the middle lamellae (Ali *et al*., 2013; Rodriguez *et al*., 2006). Guar gum forms a barrier film that protects the fruits by reducing the respiration rate, maintaining the activity of protective enzymes, and the integrity of the cell membrane (Ruelas-Chacon *et al*., 2017; Sultan *et al*., 2021). It is also fortified fruits' defense ability against microbes (Saha *et al*., 2016). Several research findings are inconsistent with the current study results; coating fruit with natural substances (chitosan, arabic gum, aloe vera, guar gum and cactus mucilage) reduced postharvest rot

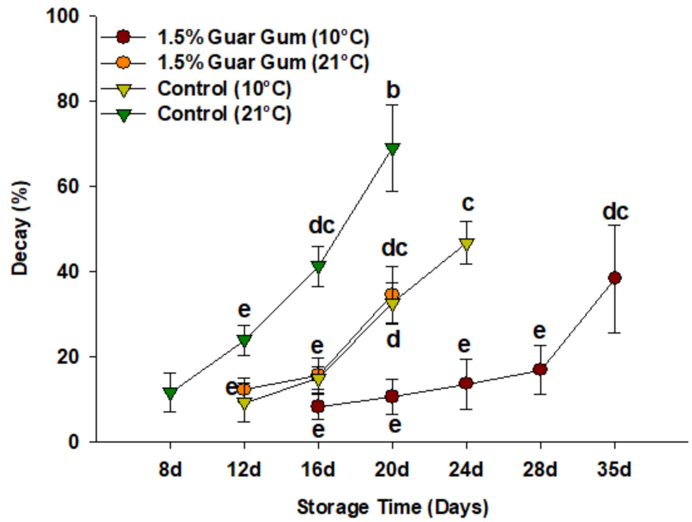

Figure 2. Impact of the coating substance guar gum on the decay percentage of tomato fruits during low (10°C) and room temperature (21°C) storage. Means followed by the same letters are not significantly different at P≤ 0.05 (SNK test). Each value consisted of three biological replicates ±standard division.

and delayed senescence (Sati and Qubbaj, 2021; Rajestary *et al*., 2020; Naeem *et al*., 2018; Ruelas-Chacon *et al*., 2017; Ali *et al*., 2013; García *et al*., 2014).

Firmness

The results showed that coating fruits with 1.5% guar gum had significantly higher fruit firmness than uncoated fruits when combined with cold (10°C) storage conditions (Figure 3). However, no significant differences were observed in firmness between coated fruits kept at room temperature and uncoated fruits kept at a cold (10°C) storage condition. Delaying fruit softening during fruit storage is very important in controlling postharvest losses. The current results showed that non-coated fruits rapidly softened and lost their texture compared to the guar gum-coated tomato fruits. Fruit softening is mainly caused by the deterioration in cell wall composition, intracellular components and cell structure during the ripening process under storage conditions (Harold *et al*., 2007; Ruelas-Chacon, *et al*., 2017). These findings have been reported for a wide range of fruits, including tomato (Naeem *et al*., 2018; Ruelas-Chacon *et al*., 2017), mango (Khaliq *et al*., 2015; Chien *et al*., 2007), and plums (Valer *et al*., 2013). Coating substances were found to create a modified atmosphere around the fruit surface, creating high levels of CO_2. Hence, decreasing respiration rate and increasing firmness values (Ruelas-Chacon *et al*., 2017) by limiting the pectin substances activity and cell wall degrading enzyme activity allows maintenance of fruit firmness during storage (Roberts, 2011).

Fruit Color Development

The color of the tomato fruits was evaluated following hunter scale (a*, L*, b*, hue, and chroma) values. The results indicated a normal color development pattern in coated and uncoated tomato fruits at both storage conditions (Figures 4-A and -E). The a* value indicates the change from green to red was increased significantly (P≤ 0.05) in non-coated fruits compared to other treatments after 4

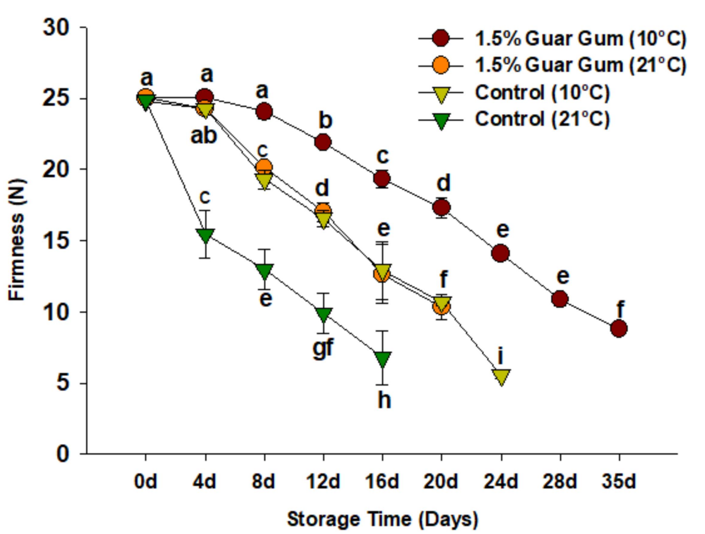

Figure 3. Impact of the coating substance guar gum on fruit firmness (N) of tomato during low (10°C) and room temperature (21°C) storage. Means followed by the same letters are not significantly different at P≤ 0.05 (SNK test). Each value consisted of three biological replicates ±standard division.

days in storage at room storage conditions (Figure 4-B). The same pattern was observed in other color parameters. The 1.5% guar gum coating treatments combined with cold (10°C) storage significantly (P≤ 0.05) delayed the color development in tomato fruits. This positive effect on delaying the color development of tomatoes was revealed by the significant color parameters L* (brightness), a* (red color intensity), b* (yellow color intensity), hue (h), and Chroma (C*) reservation compared with the control (untreated) fruit (Figure 4 A and E). The number of days required for coated tomato fruits under room temperature to develop color from pink to full red was 16 days, compared to 8 days for uncoated fruits (Figures 4-B and -C).

No significant differences were observed in fruit color development between coated fruits kept at room temperature and non-coated fruits kept at a cold (10°C) storage condition. Therefore, up to 20 days of storage time, the guar gum coating under room temperature storage has the same effects as cold storage (10°C) on delaying fruit color from turning to red. Fruit color is an important factor in determining maturity index, fruit quality, and primary sensory parameter consumers are looking for (Le Nguyen *et al*., 2020). A clear positive influence of coating fruits with 1.5% guar gum on delaying fruit ripening was found during the current research. Ripe tomato color development resulted from 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 into chromoplast (Bathgate *et al*., 1986). Fruits coating was found to delay the degradation of chlorophyll, synthesis of lycopene, and the ripening process compared to non-coated fruits (Yaman and Bayoindirli, 2002). However, this delayed fruit color development could be attributed to the modified atmosphere surrounding the fruits, reduced O_2 concentration and increased CO_2 concentration, reducing respiration and ethylene production rate in climacteric fruits (Pila *et al*., 2010); therefore, delaying ripening and the associated changes in fruit color development. These findings are in agreement with the coating of tomatoes with other natural substances (Sati and Qubbaj, 2021; Ruelas-Chacon *et al*., 2017).

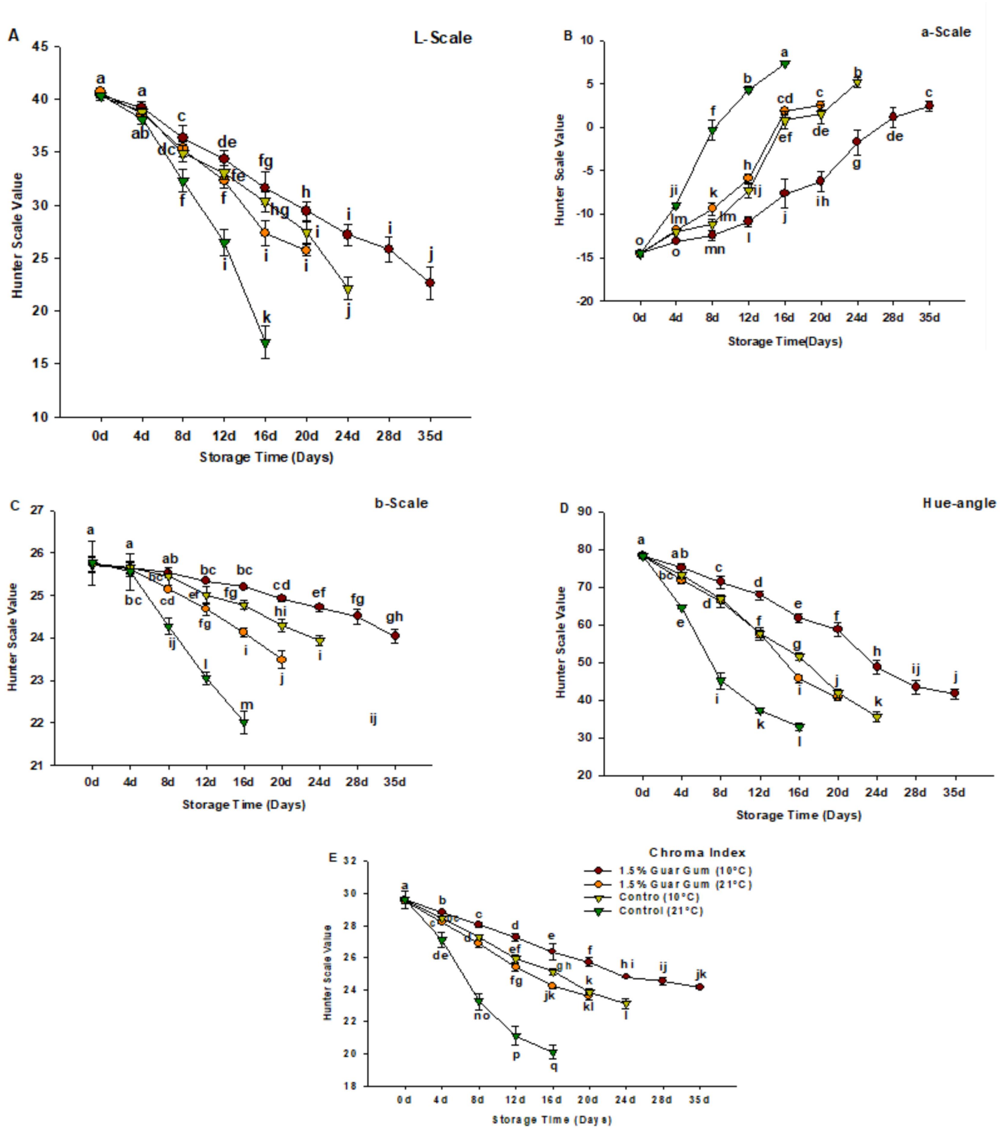

Figure 4. Impact of the guar gum coating on fruit color development of tomato during storage at room temperature (21°C) and at cold storage (10°C), including luminosity L-scale (A), a-index (B), b-index (C), hue angle (D), and chroma (E). Means followed by the same letters are not significantly different at P≤ 0.05 (SNK test). Each value consisted of three biological replicates ±standard division.

Titratable Acidity (TA)

The current study revealed a gradual decrease in TA with the storage time for all treatments at both storage conditions (Figure 5-A). After 4 days of storage till the end of the experiment, the TA value was significantly higher (P≤ 0.05) in fruits coated with 1.5% guar gum and kept at cold (10°C) storage conditions. The result also showed no significant (P≤ 0.05) difference in TA between 1.5% guar gum-coated fruits kept at room temperature (21°C) and uncoated fruits and stored at cold (10°C) storage (Figure 5A). Guar gum postharvest coating delayed the decline in concentrations of TA. Also, fruits stored in the cold storage condition showed the lowest reduction of TA (Figure5-A). These reduced TA levels are attributed to the delayed ripening process in coated tomato fruits with natural substances (Ruelas-Chacon *et al*., 2017). A similar results pattern was found in tomato fruit coated with gum arabic (Sati and Qubbaj, 2021; Ali *et al*., 2013), Aloe vera (García *et al*., 2014), or guar gum stored at room temperature (Ruelas-Chacon *et al*., 2017).

Total Soluble Solid (Brix)

The Total Soluble Solid (TSS) content gradually increased after 4 days of storage in all tomato fruits during the entire storage period (Figure 5-B). A significant (P≤ 0.05) reduction in TSS was recorded in fruit coated with 1.5% guar gum and stored at cold (10°C) storage compared to other treatments, while no significant differences (P≤ 0.05) were found between fruits coated with 1.5% guar gum and kept at room temperature (21°C) and uncoated fruits stored at cold (10°C) storage (Figure 5-B). The TSS level rises during the ripening of tomato fruits due to the hydrolysis of starch into mono-saccharides; glucose, fructose, and sucrose (Maduwanthi *et al*., 2019). However, compared to uncoated fruits, coating with guar gum showed a significant (P≤ 0.05) delay in enhanced changes in the TSS concentration and the ripening process. Therefore, the modified semi-permeable film formed around the fruit, which resulted in a modified atmospheric condition of low O_2 and elevated CO_2 concentrations that might delay the fruit ripening. Hence, the respiration and ethylene production rate in climacteric fruits will be markedly reduced (Yaman and Bayoindirli, 2002). Therefore, Postharvest fruit coating delays ripening and the associated raised changes in TSS (Pila *et al*., 2010). A similar pattern in TSS change was reported in tomato fruit coated with Arabic gum (Sati and Qubbaj, 2021; Ali *et al*., 2013), Aloe vera (García *et al*., 2014) and guar gum stored at room temperature (Ruelas-Chacon *et al*., 2017).

Ripening Index

An increased ripening index pattern was found during the storage time for all coated and uncoated fruits (Figure 5-C). However, uncoated fruits kept at room temperature showed a significantly (P≤ 0.05) sharp increase from day 4 of storage until the termination day of the experiment, while the 1.5% guar gum-coated fruits kept at cold (10°C) storage showed a significant (P≤ 0.05) slower ripening rate compared to uncoated fruits and ambient storage temperature. On the other hand, no significant difference was found in the maturity index between the 1.5% guar gum-coated fruits kept at room temperature (21°C) and uncoated fruits stored at cold (10 °C) storage (Figure 5-C). In general, coated tomato fruits with natural guar gum require more time to mature fully. In addition, coating with guar gum, a natural substance, lowered the rate of respiration, thereby delaying the conversion of organic acids and fruit ripening (Pila *et al*., 2010; Yaman and Bayoindirli, 2002).

CONCLUSIONS

The current study showed that 1.5% guar gum coating positively affected tomato fruits' physical and chemical properties. The fruits' overall quality was maintained for up to 35 days when coated with 1.5% guar gum and combined with cold (10°C) storage. In addition, coating tomato fruit with guar gum and subsequently storing it for 20 days at room temperatures (21°C) preserved the postharvest quality: firmness, titratable acidity, soluble solids, also weight loss and decay rate were reduced. Also, guar gum-coated fruits stored at the room temperature had no significant difference in fruit firmness and acceptable organoleptic quality with non-coated fruits stored at low-temperature conditions. Therefore, guar gum could be an alternative to cold storage, as it is environmentally friendly and more economical than cold storage, especially in developing countries.

ACKNOWLEDGEMENTS

The authors are grateful to An-Najah National University, the National Agriculture Research Center (NARC) and the Ministry of Agriculture (MoA) for facilitating the accomplishment of this research.

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پوشش میوه‌های گوجه‌فرنگی با صمغ گوار پس از برداشت، رسیدن میوه، عمر نگهداری و کیفیت گوجه را در شرایط محیط یا سرد خانه تعدیل می‌کند

ت. کوباج، و ف. ساتی داراگما

چکیده

علاقمندی روبه رشد به پوشش‌های خوراکی طبیعی برای جایگزینی واکسهای تجاری (commercial waxing)، باعث حفظ کیفیت محصولات کشاورزی پس از برداشت می شود. در این پژوهش، تغییرات فیزیکی و شیمیایی میوه‌های گوجه‌فرنگی پس از پوشش دهی با ۱.۵ % صمغ گوار و نگهداری در دمای اتاق یا شرایط سرد خانه بررسی شد. میوه های گوجه فرنگی در "مرحله برداشت" (breaker stage) در محلول صمغ گوار ۱.۵% به مدت ۱ دقیقه خیسانده شد و سپس در دمای اتاق (۲۱ درجه سانتی گراد، نم نسبی45 ٪) یا سرد خانه (۱۰ درجه سانتی گراد، نم نسبی85 ٪) نگهداری شد. نتایج نشان داد که پوشش صمغ گوار به طور معنی‌داری (P ≥ ۰/۰۵) سفتی میوه و ویژگی‌های کیفی ارگانولپتیک (organoleptic) را حفظ کرد. کاهش وزن میوه، درصد پوسیدگی، اسیدیته قابل تیتراسیون (TA)، کل مواد جامد محلول (TSS) و تکامل رنگ میوه در میوه‌های پوشیده شده با صمغ گوار در مقایسه با میوه‌های بدون پوشش به طور قابل‌توجهی حفظ شد. صمغ گوار همراه با دمای پایین می تواند کیفیت میوه گوجه فرنگی را به مدت ۳۵ روز حفظ کند. افزون بر این، میوه های پوشش داده شده با ۱.۵ % صمغ گوار که در دمای اتاق نگهداری می شوند، کیفیت میوه ها را همانند میوه های بدون پوشش ولی ذخیره شده در دمای سرد حفظ می کند. بنابراین، صمغ گوار می تواند جایگزینی برای انبارداری سرد باشد، زیرا با محیط زیست سازگار بوده و به ویژه در کشورهای در حال توسعه مقرون به صرفه تر از انبار سرد است.