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Effect of Chitosan Coating on Physiological Responses and Nutritional Qualities of Tomato Fruits during Postharvest Storage

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Authors' contributions

This work was carried out in collaboration among all authors. Authors NS and MAP conduct the experiment, collect the data and managed the analyses of the study. Author HMZ designed the study, managed the literature and wrote the manuscript. Authors SS and HPS helped in manuscript preparation and analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

This experiment was conducted to evaluate the effect of chitosan coating on physiological responses and nutritional qualities of tomato fruits at postharvest storage. There were four treatments of chitosan viz. T0 (control), T1 (0.10%), T2 (0.20%) and T3 (0.30%), and two storage conditions viz. in refrigerator (4℃) and room temperature (≈23-25℃). The matured light yellow tomato fruit samples were collected at 10, 20, 30 and 50 days after postharvest storage to assess physiological parameters viz. shelf life and weight loss as well as to determine lycopene and mineral constituents viz. Ca, Mg, P, S, Na and K. The mean weight loss of tomato fruits were 0.64, 1.28, 1.59 and 2.28% at 4℃, while it was 0.88, 1.84, 2.60 and 4.80% at room temperature at 10, 20, 30 and 50 days after postharvest storage, respectively. The shelf life of tomato fruits ranged between 58.3-100.0, 50.0-100.0, 33.3-75.0 and 16.7-66.8% at 4℃, while the ranges were 66.8-

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100.0, 50.0-100.0, 33.3-75.0 and 0.0-41.8% at room temperature at 10, 20, 30 and 50 days after postharvest storage, respectively. As regards to weight loss and shelf life, the study results inferred that chitosan coating with 0.2% solution is useful at postharvest storage of fruits. The study results revealed that storage temperatures (4℃ and ≈23-25℃) had no effect on the total contents of different mineral element of tomato fruits but lycopene content reduced almost twice at refrigerated condition. On the other hand, the effect of chitosan coating on Ca, Mg, P, S, Na and K contents of tomato fruits at different days after postharvest storage were highly significant at both conditions. Finally, the study results concluded that 0.2% chitosan based coatings in tomato fruits proved to extend the shelf life by decreasing the decay incidence and weight loss, and refrigerated condition is better than that of room temperature.

Keywords: Chitosan coating; postharvest storage; tomato; nutritional quality.

1. INTRODUCTION

Tomato *(Lycopersicon esculentum)* is one of the most important supplementary sources of minerals, phenolics and vitamins in human diet. The estimated annual production of tomato in Bangladesh was 385 thousand metric tons in 2017-2018 fiscal year [1], which is not enough to meet up local demand for the country, thus Bangladesh government has been importing several thousand metric tons from foreign countries every year. Tomato is highly perishable, it encounters several problems in its transportation, storage and marketing [2]. Hence, postharvest losses make its production in most parts of the world unprofitable. According to Rehman et al. [3] postharvest losses in tomatoes can be as high as 25-42% globally. Thousands of tons of vegetables and fruits go to waste annually in Bangladesh due to a lack of sufficient technologies and knowledge on postharvest handling, packaging, storage and transportation. Bangladesh Bureau of Statistics report showed that postharvest loss of tomato was 27.64% while the national level loss of tomato was 64252 tons in 2015-2016 [4].

Chitosan is commercially produced from shells of crabs, shrimp and lobsters, and coastal areas of Bangladesh produce huge amount of shrimps. Thus the raw materials for chitosan production is abundant in Bangladesh, which has a wide scope of use in agricultural field. In the meantime, Department of Agricultural Chemistry of Bangladesh Agricultural University (BAU) has extracted chitosan from shells of crabs and shrimp using local techniques. Chitosan is soluble in dilute organic acids, and its coating is non-toxic and safe, and could theoretically be used as a preservative for coating fruits [5]. Chitosan exhibits antifungal activity against several fungi [6]. Meanwhile, it has been well documented that chitosan has broad-spectrum antimicrobial activity [7,8] and *in vivo* studies showed that chitosan treatment could control or delay postharvest decay of fruits and vegetables [9]. In Bangladesh, the tomato fruits not only lose their quality like consumer acceptability, nutrient status of fruits, and financial income to producers but also encounter a substantial postharvest loss. So, the research findings on appropriate postharvest treatments, packaging, temperature, etc. and their dissemination to the farmers are very important. Considering the facts stated above, this study was undertaken to assess the physiological effects of chitosan application at postharvest storage, and to determine nutritional qualities of tomato fruits at different stages of storage.

2. MATERIALS AND METHODS

2.1 Collection and Screening of Tomato Fruits

To conduct this experiment 15.0 kg of fully matured (light yellow in colour) tomato fruits (cv. *Ruposhi*) were collected from farmer's field and immediately brought to the laboratory of the Department of Agricultural Chemistry, BAU, Mymensingh. After collection, tomato fruits were screened on the basis of their uniformity in shape, size and level of maturity (colour). Almost similar shape, size and matured fruits were selected for the experiment. Damaged and disease infected fruits were removed at the beginning.

2.2 Treatments of Chitosan

Chitosan used in the experiments was collected from the Department of Agricultural Chemistry, BAU, Mymensingh, which has been extracted from shells of shrimp following the method described by Ahing and Wid [10]. There were 4

(four) treatments of chitosan used for the experiment viz. T0 (control/ no chitosan), T1 (0.10% chitosan solution), T2 (0.20% chitosan solution) and T3 (0.30% chitosan solution).

2.3 Preparation of Chitosan Coating Solutions

To prepare 1.0 L of 0.10, 0.20 and 0.30% chitosan solutions, at first exactly 1.0, 2.0 and 3.0 gm of chitosan, respectively were dissolved in three different beakers containing about 25 mL of glacial acetic acid. Then the content was shaken well until chitosan dissolved completely. After then dissolved chitosan solution was transferred into a litre volumetric flask containing about 800 mL of distilled water and shaken well. Finally, the volume was made up to the mark with distilled water. Acid solution without chitosan was used as control. The pH of the solution was adjusted to 5.0 with 0.1 M NaOH solution.

2.4 Postharvest Application of Chitosan

Previously selected 7-8 tomato fruits were dipped for 30 seconds in each treatment of chitosan (pH 5.0), and same number of fruits were also dipped similarly in the distilled water having pH 5.0 (control). All treated fruits were allowed to air dried for 1 hr at 20°C. One group was regarded as a replicate, and there were three replications and two conditions (room temp. and refrigerated temp.) for the experiment. Thus, there were 24 (4×3×2) groups of tomato fruits in this experiment. The treated and control fruits were packaged in zip-lock bags, to maintain the relative humidity (RH) about 90-95%, and finally, the samples were stored at room (≈23-25°C) and refrigerated (4°C) temperature.

2.5 Data Recorded and Statistical Analysis

Data on shelf life and weight loss of tomato fruits were measured and recorded at 10, 20, 30 and 50 days after storage. One tomato fruit from each replication was also collected randomly at the same interval for chemical analyses. Obtained data were analysed statistically and the mean differences of the treatments were adjusted by least significant difference (LSD) test with the help of computer package M-STAT.

2.6 Nutritional Quality of Tomato Fruits

One tomato fruit sample from each replication was collected at 0 (initial), 10, 20, 30 and 50 days interval for the determination lycopene and mineral contents (Ca, Mg, P, K, Na and S). Lycopene is responsible for the red colour of tomato. The carotenoids in the sample are extracted in acetone and then taken up in petroleum ether following the method described by Sadasivam and Manickam [11]. To determine different nutrient elements, collected fruit samples were cut into small pieces using a sharp stainless steel knife and dried in an electric oven at 50°C temperature for about 72 hrs. Then the samples were ground by a grinding mill and used to prepare tomato fruit extract by wet oxidation method using di-acid mixture as described by Singh et al. [12]. Among the nutrient elements, Ca and Mg were determined by titrimetrically, P and S were measured spectrophotometrically (660 and 425 nm absorbance wavelength, respectively; T60 UV-Visible Spectrophotometer, PG Instrument, UK) and Na and K were estimated by flame photometrically (589 and 766 nm emission wavelength, respectively; 0.2 ppm limit of detection; Jenway PFP7, Flame Photometer, UK) as mentioned by Singh et al. [12].

3. RESULTS AND DISCUSSION

3.1 Weight Loss of Tomato Fruits

Weight losses of tomato fruits in storage at 4°C (in refrigerator) and room temperature are presented in Fig. 1. At 4°C temperature, the ranges of weight loss of tomato fruits were 0.44-0.92, 0.97-1.74, 1.13-2.24 and 1.58-3.45% at 10, 20, 30 and 50 days after postharvest storage (DAPS), respectively. It is apparent from Fig. 1 that the rate of weight loss was higher in control (T0) treatment with the storage time at both temperature. While postharvest chitosan coating treatment significantly decreased weight loss with increasing concentrations. But there was very little difference in weight loss of tomato fruits at different storage time between the treatments T2 and T3. The study results inferred that chitosan coating with T3 (0.3% solution) is the best to retard water loss of tomato fruits in storage at 4°C temperature.

At room temperature, the ranges of weight loss of tomato fruits were 0.70-1.24, 1.40-2.70, 1.75-4.48 and 3.12-8.54% at 10, 20, 30 and 50 DAPS, respectively. Present study revealed that the weight losses of tomato fruits were almost twice at different storage time, when they were stored at room condition. Finally, the study results inferred that chitosan coating may be used to

prevent water loss of tomato fruits at postharvest storage and refrigerated condition is better than that of room temperature. Similar observation was also reported by Meng et al. [13] in case of table grape fruit stored at 20° and 0℃ temperature. Chien et al. [14] also reported that coating of citrus fruits with low molecular weight chitosan significantly decrease weight loss. They also stated that postharvest water retention prevents rapid deterioration by shriveling of fruits and before shriveling becomes apparent, postharvest water loss may also alter metabolism and, in some instances, accelerate fruit ripening. Therefore, reducing water loss from fruit during storage or ripening helps to maintain the quality of fruit.

3.2 Shelf Life of Tomato Fruits at Storage

Shelf lives of tomato fruits in storage at 4℃ (in refrigerator) and room temperature are presented in Fig. 2. At 4℃ temperature, the ranges of shelf life of tomato fruits were 58.3-100.0, 50.0-100.0, 33.3-75.0 and 16.7-66.8% at 10, 20, 30 and 50 DAPS, respectively. It is apparent from Fig. 2 that the shelf life of tomato fruits decreased significantly in control (T0) treatment with the storage time at both conditions. But postharvest chitosan coating treatment significantly increased shelf life of tomato fruits with increasing concentrations. It is also prominent from Fig. 2 that the treatment T3 (0.3% chitosan solution) could maintain shelf life of tomato fruits 100% up to 20 days after storage. Furthermore, the shelf lives of tomato fruits at storage were 75 and 66.8% at 30 and 50 days, respectively with the same treatment. So, T3 treatment can be used for long time storage of tomato fruits at postharvest storage at 4℃ temperature.

At room temperature, the ranges of shelf lives of tomato fruits were 66.8-100.0, 50.0-100.0, 33.3-75.0 and 0.0-41.8% at 10, 20, 30 and 50 DAPS, respectively. Present study results revealed that there was no significant difference for shelf life of tomato fruits in between the treatments T2 and T3. So, it can be inferred from this study that chitosan coating may be used to extend shelf life of tomato fruits at postharvest storage and refrigerated condition is better than that of room temperature, which might be due to controlling effect of chitosan on postharvest diseases of tomato fruits caused by different organisms. Similar observation was also reported by Liu et al. [15] and they stated that chitosan at 0.5 and 1.0% could significantly decrease gray mould and blue mould caused by *Botrytis cinerea* and *Penicillium expansum* in tomato fruit stored at 25 and 2℃ temperature, respectively. Furthermore, Romanazzi et al. [16] reported that chitosan application had shown promising disease control, at both preharvest and postharvest stages. According to their report, chitosan showed a dual mode of action on the pathogen and on the plant, as it reduces the growth of decay-causing fungi and food borne pathogens and induces resistance responses in the host tissues.

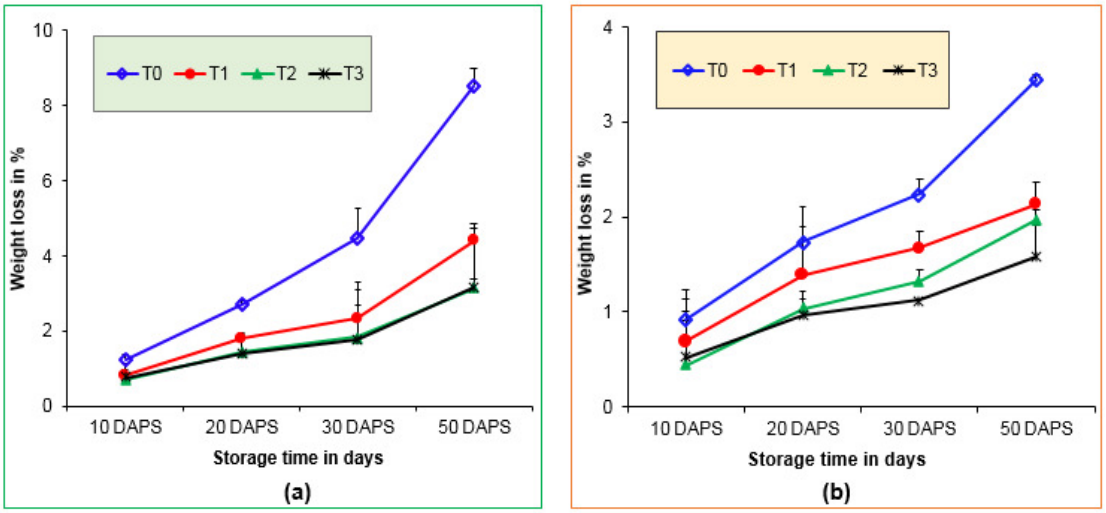

Fig. 1. Effects of different doses of chitosan coating on weight loss (in%) of tomato fruits at different days after post-harvest storage (DAPS) at room temperature (a) and 4℃ temperature (b). Each value is the mean for three replicates, and vertical bars indicate the standard errors

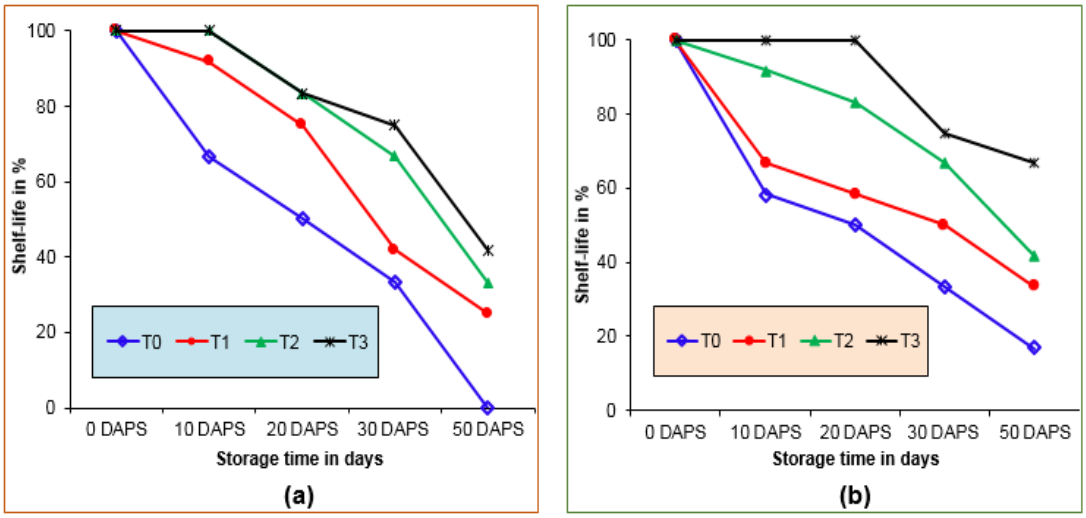

Fig. 2. Effects of different doses of chitosan coating on shelf-life (in%) of tomato fruits at different days after post-harvest storage (DAPS) at room temperature (a) and 4℃ temperature (b). Each value is the mean for three replicates

3.3 Lycopene Content of Tomato Fruits

Lycopene is one kind of carotenoids responsible for the red colour of tomato. The amount of lycopene in tomato fruits at postharvest storage at 4^0C (in refrigerator) and room temperature are presented in Fig. 3. Epidemiological, as well as cell culture and animal studies suggest that lycopene and the consumption of lycopene containing foods may reduce cancer or cardiovascular disease risk [17]. At room temperature, the amount of lycopene present in tomato fruits ranged between 4.07-6.86, 3.76-5.01, 2.64-3.12 and 0.0-3.08 mg in 100 gm tomato fruits at 10, 20, 30 and 50 DAPS, respectively. The amounts of lycopene were higher compared to fresh tomato (3.55 mg in 100 gm tomato fruits) at 10 and 20 DAPS, which might be due to extend physiological process during postharvest storage at room temperature.

At 4^0C temperature, the amount of lycopene present in tomato fruits ranged between 1.27-2.32, 0.78-1.54, 0.51-1.14 and 0.39-1.15 mg in 100 gm tomato fruits at 10, 20, 30 and 50 DAPS, respectively. These amounts were smaller compared to fresh tomato (3.55 mg in 100 gm tomato fruits), which might be due to low temperature during postharvest storage (4^0C). It is evident from Fig. 3 that coating of chitosan at different doses had no effect on the lycopene content of tomato fruits at both temperatures. However, present study revealed that in most cases, the amount of lycopene in tomato fruits decreased with postharvest storage time. After bringing the fruit from room temperature to refrigerator temperature, the abundance of most volatiles was greatly reduced within 3 to 5 hrs [18]. Exposure to storage temperatures below 13℃ may induce significant chilling injury in tomato fruit. Severity of chilling injury is dependent on the length of the exposure to cold temperature as well as on the ripening stage of the tomato fruit. Furthermore, refrigerator storage at around 4-6℃ temperature may cause a severe alteration in fruit quality of tomato including fruit discolouration and lycopene degradation. Following prolonged storage at chilling temperature, a decrease in lycopene content was observed due to a decreased synthesis and/or an increased breakdown [19, 20]. However, present study revealed that in most cases, the amount of lycopene in tomato fruits decreased and/or remained unchanged with postharvest storage time. Lycopene in fresh tomato fruits occurs essentially in the all-trans configuration. The main causes of tomato lycopene degradation during processing are isomerization and oxidation [21]. Isomerization converts all-trans isomers to cis-isomers due to additional energy input and results in an unstable, energy-rich station.

3.4 Nutrient Contents of Tomato Fruits

3.4.1 Calcium (Ca) content

Effect of chitosan application on Ca content of tomato fruits at different days after postharvest

storage at both temperatures were highly significant at 1% level of probability (Tables 1 and 2). At refrigerated condition, the highest amounts of Ca were recorded from 10, 30 and 50 DAPS at T3 (0.387%), T2 (0.514%) and T3 (0.518%) treatments, respectively. But the lowest amounts of Ca were found from 10 and 50 DAPS at T1 treatment and 30 DAPS at control (T0) treatment. On the other hand, at room temperature, the maximum amounts of Ca were recorded from 10, 30 and 50 DAPS at T3 (0.421%), T2 (0.340%) and T2 (0.624%) treatments, respectively. Instead, the minimum amounts of Ca were found from control treatments at different DAPS at room temperature. The amounts of Ca in tomato fruits at different DAPS both at 4℃ and room temperatures were comparatively higher than the fresh tomato fruits (Tables 1 and 2). So, in context of Ca, it may be inferred that the treatment T2 (chitosan application at 0.2% solution) can be recommend for postharvest storage of tomato fruits. It is also evident from the present study that storage condition (4℃ and room temperature) did not affect Ca content in postharvest storage of tomato fruits. Paul and Shaha [22] obtained 27.0±1.2 mg% Ca in tomato fruits collected from the northern region of Bangladesh. According to Parvin et al. [23], the tomato variety *Roma VF* contained 0.32 to 0.69% Ca, which is almost at par with the present study.

3.4.2 Magnesium (Mg) content

Effect of different doses of chitosan coating on Mg content of tomato fruits at different DAPS at 4℃ and room temperatures are presented in Tables 1 and 2, respectively. Mg contents of tomato fruits were highly significant at 1% level of probability at both conditions. At 4℃ temperature, the highest amounts of Mg were 0.181, 0.165 and 0.224% from 10, 30 and 50 DAPS, respectively at T2 treatment (0.2% chitosan solution). Alternatively, the lowest amounts of Mg were recorded from 10, 30 and 50 DAPS at control (T0) treatment. Present study results found that the higher doses of chitosan solution (T3 = 0.3% solution) at refrigerated condition reduces the amount of Mg in tomato fruits at different DAPS.

In case of room temperature, the maximum amounts of Mg were recorded from T3 (0.235%), T2 (0.252%) and T3 (0.176%) treatments at 10, 30 and 50 DAPS, respectively. Alternatively, the minimum amounts of Mg were found from control (T0) treatment at different DAPS, which were statistically similar with T1 treatments of 10 and 30 DAPS. The amounts of Mg in tomato fruits at

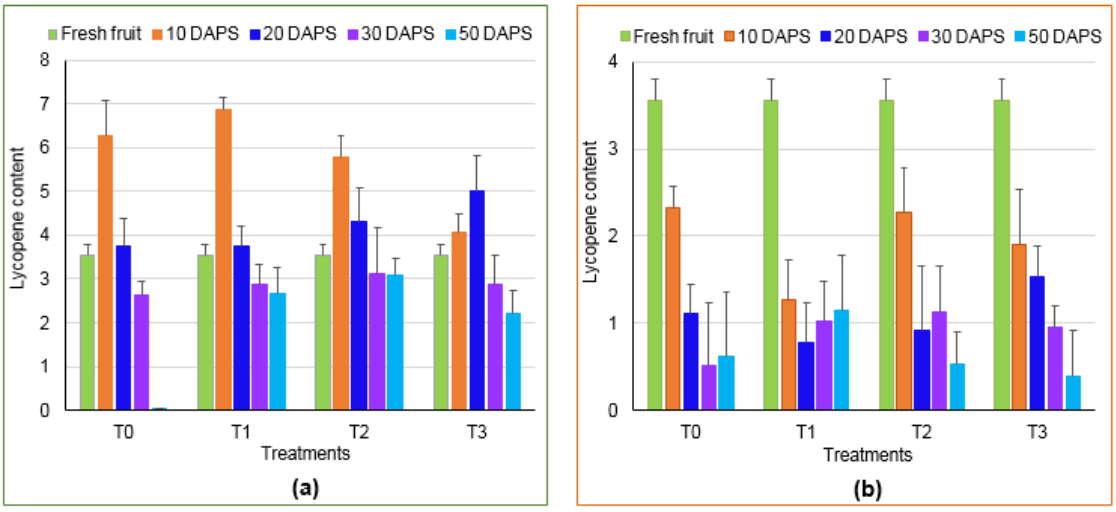

Fig. 3. Effects of different doses of chitosan coating on lycopene content (mg in 100 gm sample) in tomato fruits at different days after post-harvest storage (DAPS) at room temperature (a) and 4℃ temperature (b). Each value is the mean for three replicates, and vertical bars indicate the standard errors

Table 1. Effects of different doses of chitosan coating on mineral composition (Ca, Mg, P, S, Na and K) of tomato fruits at different days after post-harvest storage (DAPS) at 4℃ temperature

Treatments	Ca (%)			Mg (%)			P (%)			S (%)			Na (%)			K (%)		
	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS
T0	0.312b	0.233d	0.402c	0.070c	0.070c	0.129c	0.004b	0.007b	0.001c	0.145b	0.226a	0.191c	0.214c	0.243c	0.230c	0.273c	0.372b	0.365c
T1	0.297b	0. 463b	0.367d	0.094b	0.048d	0.192b	0.002c	0.008b	0.005b	0.152b	0.199b	0.215b	0.286ab	0.282b	0.248c	0.225d	0.328c	0.398b
T2	0.386a	0.514a	0.495b	0.181a	0.165a	0.224a	0.010a	0.012a	0.005b	0.187a	0.202b	0.261a	0.305a	0.209d	0.307a	0.404a	0.307c	0.432a
T3	0.387a	0.321c	0.518a	0.094b	0.145b	0.139c	0.004b	0.007b	0.007a	0.202a	0.239a	0.168d	0.268b	0.310a	0.281b	0.343b	0.404a	0.244d
$LSD_{0.05}$	0.0197	0.0146	0.0178	0.0103	0.0168	0.0119	0.0008	0.0020	0.0013	0.0168	0.0188	0.0157	0.0197	0.0157	0.0188	0.103	0.231	0.215
Level of significance	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	2.98	2.01	2.10	4.69	8.60	3.92	10.48	12.11	17.21	5.27	4.53	4.04	3.97	3.17	3.82	1.85	3.52	3.11
Average content in fresh fruit	0.273 ± 0.036			0.066 ± 0.018			0.003 ± 0.0002			0.158 ± 0.017			0.234 ± 0.021			0.381 ± 0.063		

*** = Significant at 1% level of probability; T0 = control; T1 = 0.10% chitosan solution; T2 = 0.20% chitosan solution and T3 = 0.30% chitosan solution*

Table 2. Effects of different doses of chitosan coating on mineral composition (Ca, Mg, P, S, Na and K) of tomato fruits at different days after post-harvest storage (DAPS) at room (≈23-25℃) temperature

Treatments	Ca (%)			Mg (%)			P (%)			S (%)			Na (%)			K (%)		
	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS	10 DAPS	30 DAPS	50 DAPS
T0	0.233c	0.295b	0.318c	0.093c	0.179c	0.071c	0.008b	0.001c	0.008	0.221b	0.198c	0.262b	0.309b	0.259b	0.356b	0.296c	0.379ab	0.393b
T1	0.269b	0.296b	0.478b	0.094c	0.179c	0.093b	0.008b	0.002b	0.008	0.161c	0.239b	0.228c	0.251d	0.267ab	0.384a	0.294c	0.344c	0.365c
T2	0.266b	0.340a	0.624a	0.207b	0.252a	0.072c	0.009ab	0.008a	0.008	0.253a	0.291a	0.358a	0.353a	0.266ab	0.393a	0.422a	0.359bc	0.435a
T3	0.421a	0.308b	0.441b	0.235a	0.210b	0.176a	0.011a	0.002b	0.007	0.202b	0.229b	0.289b	0.272c	0.281a	0.394a	0.312b	0.395a	0.418a
$LSD_{0.05}$	0.0198	0.0197	0.0963	0.0168	0.0084	0.0133	0.0021	0.0006	0.0017	0.027	0.013	0.029	0.017	0.018	0.025	0.119	0.231	0.238
Level of significance	**	**	**	**	**	**	**	**	ns	**	**	**	**	**	**	**	**	**
CV (%)	3.51	3.42	11.01	5.72	2.24	6.58	12.37	9.56	12.19	6.73	2.84	5.38	3.04	3.51	3.40	2.01	3.34	3.14
Average content in fresh fruit	0.273 ± 0.036			0.066 ± 0.018			0.003 ± 0.0002			0.158 ± 0.017			0.234 ± 0.021			0.381 ± 0.063		

*** = Significant at 1% level of probability; ns = not significant; T0 = control; T1 = 0.10% chitosan solution; T2 = 0.20% chitosan solution and T3 = 0.30% chitosan solution*

different days after postharvest storage both at 4℃ and room temperatures were comparatively higher than the fresh tomato fruits (Tables 1 and 2). So, in context of Mg, it may be inferred that the treatment T2 (chitosan application at 0.2% solution) can be recommended for postharvest storage of tomato fruits. It is also evident from the present study that storage condition (4℃ and room temperature) did not affect Mg content in postharvest storage of tomato fruits. Paul and Shaha [22] reported 17.0±1.8 mg% Mg in tomato fruits, while Olaniyi et al. [24] found 0.222% Mg. Similarly, Cole et al. [25] reported that tomato fruits contained 0.167% (DW) Mg and these results are almost at par with the present study.

3.4.3 Phosphorus (P) content

There were highly significant difference at 1% level of probability among the treatments of chitosan coating on P content of tomato fruits at different DAPS at both temperatures, but at room temperature, P content at 50 DAPS was insignificant (Tables 1 and 2). At 4℃ temperature, the highest amounts of P were 0.01, 0.012 and 0.007%, which were obtained from 10, 30 and 50 DAPS, respectively at T2 and T3 treatments. Instead, at 10, 30 and 50 DAPS the lowest amounts of P were recorded from T1 and T0 treatments, respectively. On the other hand, at room temperature the maximum amounts of P were recorded from T3 (0.011%), T2 (0.008%) and T0-T2 (0.008%) treatments at 10, 30 and 50 DAPS, respectively, while the minimum amounts of P were found from control treatments at 10 and 30 DAPS. The amounts of P in tomato fruits at different DAPS both at 4^0C and room temperatures were comparatively higher than the fresh tomato fruits (Tables 1 and 2). So, in context of P, it may be inferred that the treatment T2 (chitosan application at 0.2% solution) can be recommended for postharvest storage of tomato fruits. It is also evident from the present study that storage condition (4^0C and room temperature) did not affect P content in postharvest storage of tomato fruits. Paul and Shaha [22] reported 28.0±1.8 mg% P in tomato fruits collected from the northern region of Bangladesh. But Kadiri et al. [26] reported 1.02±0.01 mg kg^{-1} P in tomato fruits, which was almost similar to the present study.

3.4.4 Sulphur (S) content

Effect of chitosan coating on S content of tomato fruits at different DAPS at both temperatures were significant at 1% level of probability (Tables 1 and 2). In case of refrigerated condition, the highest amounts of S were recorded from T3 (0.202%), T3 (0.239%) and T2 (0.261%) treatments at 10, 30 and 50 DAPS, respectively, while the lowest amounts of S were obtained at 10 and 50 DAPS from control (T0) treatment and at 30 DAPS from T1 treatment. On the other hand, at room temperature, the maximum amounts of S were recorded at 10, 30 and 50 DAPS and the contents were 0.253, 0.291 and 0.358%, respectively which all were obtained from T2 (0.2% chitosan solution) treatment. Alternatively, the minimum amounts of S were obtained at 10 and 50 DAPS from T1 treatment and at 30 DAPS from control (T0) treatment. The mean amounts of S in tomato fruits at different days after postharvest storage at room temperatures were almost similar to the fresh tomato fruits but the amounts were little smaller at different DAPS at 4℃ (Tables 1 and 2). However, in context of S, it may be inferred that the treatment T2 (chitosan application at 0.2% solution) can be recommend for postharvest storage of tomato fruits. It is also evident from the present study that refrigerated condition (4℃) reduced S content in postharvest storage of tomato fruits compared to room temperature. According to Mukta et al. [27], the content of S in tomato fruits varied from 0.05 to 0.39%, which is almost at par with the present study.

3.4.5 Sodium (Na) content

There were highly significant difference among the treatments of chitosan coating on Na content of tomato fruits at different DAPS at both temperatures (Tables 1 and 2). In case of refrigerated condition, the highest amounts of Na were 0.305, 0.310 and 0.307%, which obtained from T2 and T3 treatments at 10, 30 and 50 DAPS, respectively, while the lowest amounts of Na were recorded from control (T0) treatment at 10, 30 and 50 DAPS. On the contrary, at room temperature, the maximum amounts of Na were recorded from T2 (0.353%), T3 (0.281%) and T3 (0.394%) treatments at 10, 30 and 50 DAPS, respectively. But the both treatments of T1 and T2 were statistically similar with T3 at 30 and 50 DAPS. However, the minimum amounts of Na were found from control (T0) treatments at 30 and 50 DAPS. The amounts of Na in tomato fruits at different DAPS both at 4^0C and room temperatures were comparatively higher than the fresh tomato fruits (Tables 1 and 2). So, in context of Na, it may be inferred that the treatment T2 (chitosan

application at 0.2% solution) can be recommended for postharvest storage of tomato fruits. Paul and Shaha [22] reported 5.5±0.9 mg% Na in tomato fruits collected from the northern region of Bangladesh, while Kadiri et al. [26] found 7.73±0.9 mg kg^{-1} Na. However, Na concentration obtained by this study was greater than the reports stated above.

3.4.6 Potassium (K) content

Effect of chitosan coating on K content of tomato fruits at different DAPS at both temperatures were significant at 1% level of probability (Tables 1 and 2). At 4℃ temperature, the highest amounts of K were recorded from T2 (0.404%), T3 (0.404%) and T2 (0.432%) treatments at 10, 30 and 50 DAPS, respectively, while the lowest amounts of K were obtained from T1, T2 and T0 treatments at 10, 30 and 50 DAPS, respectively. At room temperature, the maximum amounts of K were recorded from T2 (0.422%), T3 (0.395%) and T2 (0.435%) treatments at 10, 30 and 50 DAPS, respectively, while the minimum amounts of K were obtained from T1 treatment at 10, 30 and 50 DAPS. The mean amounts of K in tomato fruits at different DAPS at both temperatures were almost similar to the fresh tomato fruits (Tables 1 and 2). However, it is evident from the study results that tomato is a good source of K and the treatment T2 (chitosan application at 0.2% solution) can be recommend for postharvest storage of tomato fruits. According to Olaniyi et al. [24], the tomato variety *Roma VF* contained 0.148% K. On the other hand, Mukta et al. [27] stated that the K content in tomato fruits varied from 0.76 to 0.90%, which is almost twice than the present study.

4. CONCLUSION

Chitosan coating of different doses had no effect on the lycopene content of tomato fruits at both temperatures. But storage conditions (4℃ and room temperature) showed remarkable effect on lycopene content of tomato fruits. Particularly, at 4℃ temperature, the amount of lycopene reduced significantly compared to fresh tomato. On the contrary, storage conditions did not show any remarkable change in nutrient contents of tomato fruits, but the effect of chitosan coating on different nutrient contents of tomato fruits at different days after postharvest storage at both temperatures were highly significant. The study results revealed that postharvest chitosan coating treatment significantly decreased weight loss with increasing concentrations at both 4℃ and room temperatures. The rate of weight loss in tomato fruits was higher in control (T0) treatment with the postharvest storage time at both conditions. However, it is worth mentioning that the weight losses of tomato fruits were almost twice at different postharvest storage time, when they were stored at room temperature. The shelf life of tomato fruits decreased significantly in control treatment with the postharvest storage time at both 4^0C and room temperatures. Present study results revealed that there was no significant difference for shelf life of tomato fruits in between the treatments T2 and T3. So, it can be inferred from this study that chitosan coating with T2 treatment (0.2% solution) may be used to prevent weight loss and to extend shelf life of tomato fruits up to 30 days at postharvest storage, and refrigerated condition is better than that of room temperature. Finally, the study results concluded that chitosan coatings have potential for extending shelf life, improving storability, and enhancing some nutritional qualities of tomato fruits. At the same time, consumer acceptance of such coated fruits and vegetables will also have to investigate in future.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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