Effect of chitosan coating on physiological responses and nutritional qualities of tomato fruits during postharvest storage

ABSTRACT

This experiment was conducted toevaluate 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%), andtwo storage conditions viz. in refrigerator (4^0C) and room temperature(≈23-25^0C). The matured light yellowtomato 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 4^0C, 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 4^0C, while the ranges were 66.8-100.0, 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 (4^0C and ≈23-25^0C) had no effect on the total contents of different mineral element of tomato fruitsbut lycopene content reduced almost twiceat refrigerated condition. On the other hand, the effect of chitosan coating on Ca, Mg, P, S, Na and Kcontents of tomato fruits at different days after postharvest storage were highly significantat bothconditions.Finally, the study results concluded that 0.2% chitosan based coatings in tomato fruits proved to extend the shelflife 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 Rehmanet 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 farmersare 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 shrimpfollowing 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 treatedfruits were allowed to air dried for 1 hr at 20^0C. 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 (≈23-25^0C) and refrigerated (4^0C) 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 50^0C 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 4^0C (in refrigerator) and room temperature are presented in Fig. 1. At 4^0C 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)treatmentwith 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 4^0C 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 20^0 and 0^0C 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.

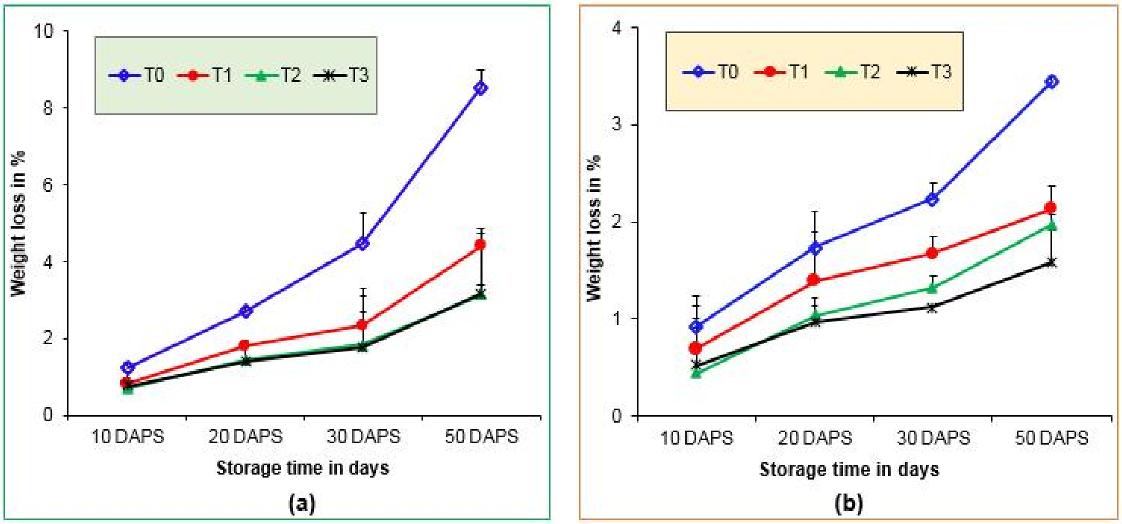

Fig. 1Effects of different doses of chitosan coating on weight loss (in %) of tomato fruits at different days after post-harvest storage (DAPS)at room temperature (a) and 4^{0}C temperature (b). Each value is the mean for three replicates, and vertical bars indicate the standard errors.

3.2 Shelf life of Tomato Fruits at Storage

Shelf lives of tomato fruits in storage at 4^{0}C (in refrigerator) and room temperature are presented in Fig. 2. At 4^{0}C 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) treatmentwith 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% upto 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^{0}Ctemperature.

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% could significantly decrease gray mould and blue mould caused by *Botrytis cinerea* and *Penicillium expansum* in tomato fruit stored at 25 and 2^{0}C 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.

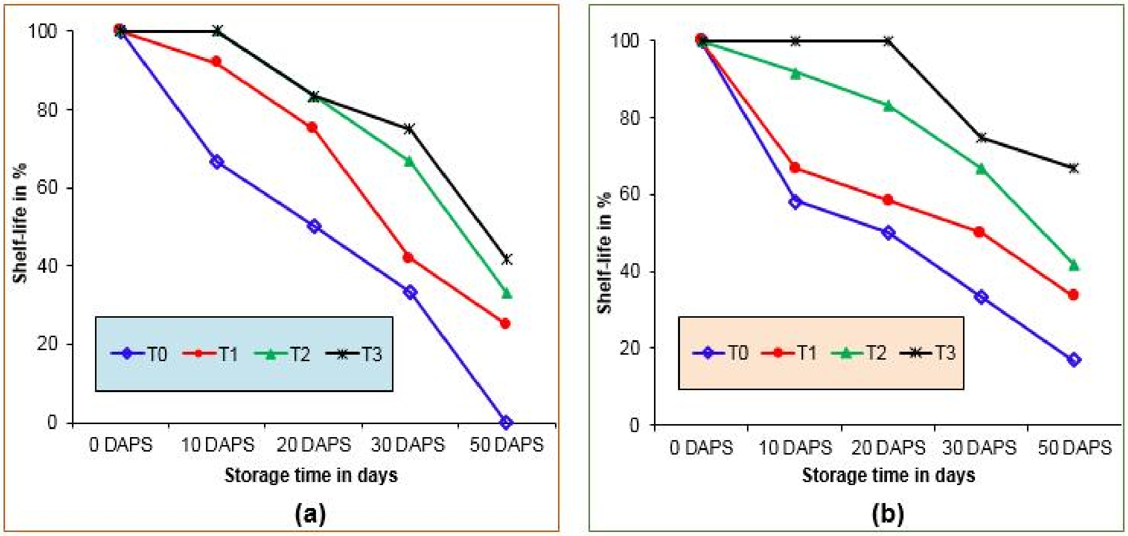

Fig. 2Effects of different doses of chitosan coating on shelf-life (in %) of tomato fruits at different days after post-harvest storage (DAPS)at room temperature (a) and 4^0C temperature (b).Each value is the mean for three replicates.

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°C 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 [19, 20]. They also stated that refrigerator storage at around 4-6°C 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. 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.

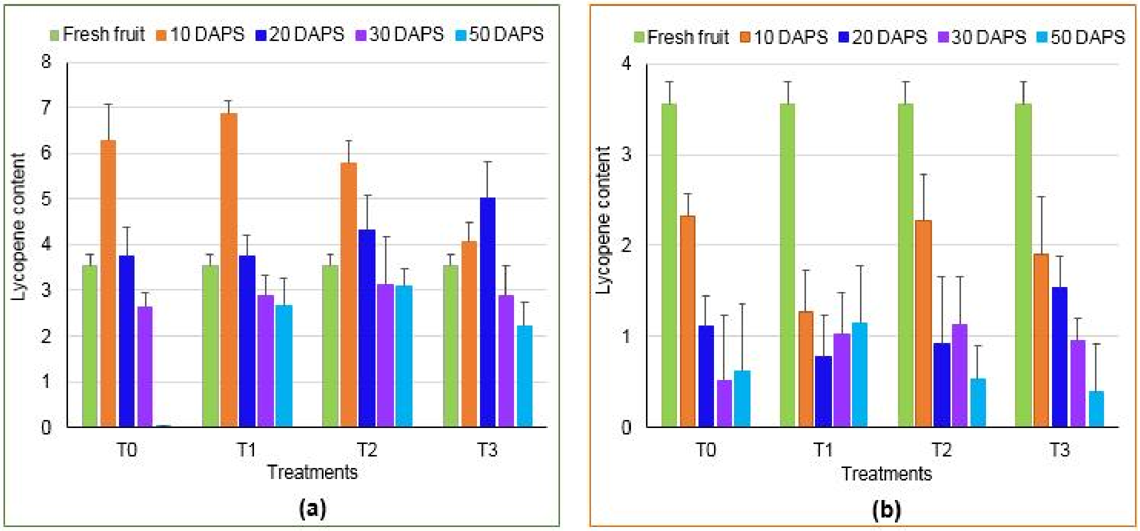

Fig. 3Effects of different doses of chitosan coating on lycopene content (mg in 100 gm sample) in tomato fruits at different days after post-harvest storage (DAPS)at room temperature (a) and 4^{0}C temperature (b).Each value is the mean for three replicates, and vertical bars indicate the standard errors.

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 T1treatment 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^{0}C 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^{0}C 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 Parvinet al. [23], the tomato variety *Roma VF* contained 0.32 to 0.69% Ca, which is almost at par with the present study.

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^{0}C 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	50DAPS
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^{0}C) 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.

3.4.2 Magnesium (Mg) content

Effect of different doses of chitosan coating on Mg content of tomato fruits at different DAPS at 4^0C 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 4^0C 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 10, 30 and 50 DAPS at T3(0.235%), T2 (0.252%) and T3 (0.176%) treatments, 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 different days after postharvest storage both at 4^0C and room temperatures were comparatively higher than the fresh tomato fruits (Tables 1and 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 (4^0C 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 1and 2). At 4^0C 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, the lowest amounts of P were recorded from 10, 30 and 50 DAPS at T1 and T0 treatments. On the other hand, at room temperaturethe maximum amounts of P were recorded from 10, 30 and 50 DAPS were0.011% (T3), 0.008% (T2) and 0.008% (T0-T2), respectively, while the minimum amounts of P were found from control treatments at 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 1and 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 10, 30 and 50 DAPS at T3(0.202%), T3 (0.239%) and T2 (0.261%) treatments, respectively, while the lowest amounts of S were obtained from 10 and 50 DAPS at control (T0)treatment and 30 DAPS at T1 treatment. On the other hand, at room temperature, the maximum amounts of S were recorded from 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 from 10 and 50 DAPS at T1 treatment and 30 DAPS at 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 4^0C (Tables 1and 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 (4^0C) 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 10, 30 and 50 DAPS, respectively at T2 and T3 treatments, while the lowest amounts of Na were recorded from 10, 30 and 50 DAPS at control(T0) treatment. On the contrary, at room temperature, the maximum amounts of Na were recorded from 10, 30 and 50 DAPS at T2(0.353%), T3 (0.281%) and T3 (0.394%) treatments, 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 1and 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 4^0C temperature, the highest amounts of K were recorded from 10, 30 and 50 DAPS at T2 (0.404%), T3 (0.404%) and T2 (0.432%) treatments, respectively, while the lowest amounts of K were obtained from 10, 30 and 50 DAPS at T1, T2 and T0 treatments, respectively. At room temperature, the maximum amounts of K were recorded from 10, 30 and 50 DAPS at T2(0.422%), T3 (0.395%) and T2 (0.435%) treatments, respectively, while the minimum amounts of K were obtained from 10, 30 and 50 DAPS at T1 treatment. The mean amounts of K in tomato fruits at different DAPS at both temperatures were almost similar to the fresh tomato fruits (Tables 1and 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 twicethan 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 (4^0C and room temperature) showed remarkable effect on lycopene content of tomato fruits. Particularly, at 4^0C 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^{0}C 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 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^{0}C 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 withT2 treatment(0.2% solution) may be used to prevent weight loss and to extend shelf life of tomato fruits up to 30 daysat 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.

ACKNOWLEDGEMENTS

This work was financially supported by the Bangladesh Agricultural University Research System (BAURES), Mymensingh-2202, Bangladesh for the financial year 2017-19 under the Project no. BAU-258/2017.

COMPETING INTERESTS

Authors have declared that no competing interests exist.”

AUTHORS’ CONTRIBUTIONS

Authors Sultana N. and Parvin M.A. conduct the experiment, collect the data and managed the analyses of the study. Author Zakir H.M. designed the study, managed the literature and wrote the manuscript. Authors Sharmin S. and Seal H.P. helped in manuscript preparation and analyses of the study. All authors read and approved the final manuscript.”

REFERENCES

1. BBS (Bangladesh Bureau of Statistics). Statistical Pocket BookBangladesh 2018.Ministry of Planning, Government of the People’s Republic of Bangladesh. Dhaka, Bangladesh. 2019.p. 148.
2. Ruth BA, LurieS. *Prolongation of Fruit Life after Harvest*. In: Hand Book of Fruit Set and Development. Shaul PM (Ed.), 1st Edition, CRC press, Boca Raton. 1986. 28 p.
3. Rehman M, Khan N, Jan I. Postharvest losses in tomato crop (a case of Peshawar valley). Sarhad J Agric.2007; 23(4):1279-1284.
4. BBS (Bangladesh Bureau of Statistics). *Crop Estimate (Tomato) Status Survey*- 2016. Ministry of Planning, Government of the People’s Republic of Bangladesh. Dhaka, Bangladesh. 2016. p. 297.

5. Hirano S, Itakura C, Seino H, Akiyama Y, Nonaka I, Kanbara N, Kawakami T. Chitosan as an ingredient for domestic animal feeds. J Agric Food Chem.1990; 38(5):1214-1217.DOI: 10.1021/JF00095A012
6. Allan CR, Hadwiger LA. The fungicidal effect of chitosan on fungi of varying cell wall composition. Exp Mycol.1979; 3:285-287.
7. Ait Barka, E., Eullaffroy, P., Clement, C. and Vernet, G. 2004. Chitosan improves development, and protects *Vitisvinifera* L. against *Botrytis cinerea*. Plant Cell Rep. 22(8): 608-614.DOI: 10.1007/s00299-003-0733-3
8. Plascencia-Jatomea M, Viniegra G, Olayo R, Castillo-Ortega MM, Shirai K. Effect of chitosan and temperature on spore germination of Aspergillus niger. Macromol Biosci.2003; 3(10): 582-586. DOI:10.1002/mabi.200350024
9. Bautista-Banos S, Hernandez-Lauzardo AN, Velazquez-del Valle MG, Hernandez-Lopez M, Ait Barka E, Bosquez-Molina E, Wilson CL. Chitosan as a potential natural compound to control pre and postharvest diseases of horticultural commodities. Crop Protec.2006; 25(2):108-118. DOI: 10.1016/j.cropro.2005.03.010
10. Ahing FA, Wid N. Extraction and characterization of chitosan from shrimp shell waste in Sabah. Transac Sci Tech. 2016; 3(1-2): 227-237.
11. Sadasivam S, Manickam A. Biochemical Methods. 2ndEdition, New Age International (P) Limited, New Delhi-110 002, India. 1996.
12. Singh D, Chhonkar PK, Pandey RN. Soil, Plant and Water Analysis: A Method Manual. IARI, New Delhi. India. 1999.
13. Meng X, Li B, Liu J, Tian S. Physiological responses and quality attributes of table grape fruit to chitosan preharvest spray and postharvest coating during storage. Food Chem.2008; 106: 501-508. DOI:10.1016/j.foodchem.2007.06.012
14. Chien P-J, Sheu F, Lin H-R. Coating citrus (Murcott tangor) fruit with low molecular weight chitosan increases postharvest quality and shelf life. Food Chem.2007; 100:1160-1164. DOI:10.1016/j.foodchem.2005.10.068
15. Liu J, Tian S, Meng X, Xu Y. Effects of chitosan on control of postharvest diseases and physiological responses of tomato fruit. Postharvest Biol Technol.2007; 44:300-306. DOI:10.1016/j.postharvbio.2006.12.019
16. Romanazzi G, Feliziani E, Banos SB, Sivakumar D. Shelf life extension of fresh fruit and vegetables by chitosan treatment. Critical Rev Food Sci Nutr., 2017; 57(3):579-601. DOI: 10.1080/10408398.2014.900474
17. Story EN, Kopec RE, Schwartz SJ, Harris GK. An Update on the health effects of tomato lycopene. Annu Rev Food Sci Technol.2010; 1:189-210. DOI:10.1146/annurev.food.102308.124120.
18. Farneti B, Alarcón AA, Papasotiriou FG, Samudrala D, Cristescu SM, Costa G, Harren FJM, Woltering EJ. Chilling-induced changes in aroma volatile profiles in tomato. Food Bioproc Technol.2015; 8(7):1442-1454. DOI: 10.1007/s11947-015-1504-1
19. Saltveit ME. Influence of heat shocks on the kinetics of chilling-induced ion leakage from tomato pericarp discs.Postharvest Biol Technol.2005; 36(1):87-92. DOI: 10.1016/j.postharvbio.2004.10.007.
20. Farneti B, Schouten RE,Woltering EJ. Low temperature-induced lycopene degradation in red ripe tomato evaluated by remittance spectroscopy. Postharvest Biol Technol.2012; 73:22-27. DOI: 10.1016/j.postharvbio.2012.05.008
21. Shi J, Le MM. Lycopene in tomatoes: chemical and physical properties affected by food processing. Critical Rev Biotechnol.2000; 20(4):293-334. DOI: 10.1080/07388550091144212
22. Paul DK,Shaha RK. Nutrients, vitamins and minerals content in common citrus fruits in the northern region of Bangladesh. Pak J Biol Sci.2004; 7(2):238-242.
23. Parvin MA, Zakir HM, Sultana N, Kafi A, Seal HP. Effect of different application methods of chitosan on growth, yield and quality of tomato. Arch Agric Environ Sci. 2019; personal comm.

24. Olaniyi JO, Akanbi WB, Adejumo TA, Akande OG. Growth, fruit yield and nutritional quality of tomato varieties. Afr J Food Sci. 2010; 4(6):398-402.
25. Cole JC, Smith MW, Penn CJ, Cheary BS, Conaghan KJ. Nitrogen, phosphorus, calcium and magnesium applied individually or as a slow release or controlled release fertilizer increase growth and yield and affect macronutrient and micronutrient concentration and content of field grown tomato plants. Sci Hortic.2016; 211:420-430. DOI: 10.1016/j.scienta.2016.09.028
26. Kadiri M, Ojewumi AW, Olawale SO. Minerals, vitamins and chloropyll contents of fruits, stems and leaves of tomato and garden egg. Pak J Food Sci.2015; 25(3):150-154.
27. Mukta S, Rahman MM, Mortuza MG. Yield and nutrient content of tomato as influenced by the application of vermicompost and chemical fertilizers. J Environ Sci Natural Resources, 2015; 8(2): 115-122. DOI: 10.3329/jesnr.v8i2.26877