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Effect of Post harvest Treatments on Physicochemical Characteristics and Shelf Life of Tomato (*Lycopersicon esculentum* Mill.) Fruits during Storage[1]

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Abstract: The physicochemical characteristics and shelf life of tomato fruits treated with Gibberellic acid (0.1, 0.3 and 0.5%), Calcium chloride (0.5, 1 and 1.5%) and Salicylic acid (0.1, 0.2 and 0.4mM) were studied. All tested treatments indicated a significant delay in the change of weight loss, titrable acidity, total soluble solids, decaying percentage, sugar accumulation, chlorophyll degradation and carotenoids accumulation in tomato fruits of experimental set than that of the control set. Moreover, the physicochemical analysis of tomato fruits of experimental set revealed that it also contain higher amount of ascorbic acid and phenolic content. The significant impact of treatment is found on the least decay percentage in the order of fruits treated with GA_3 0.1%, $CaCl_2$ 1.5% and SA 0.4mM. Hence, it could be concluded that post harvest chemical treatment with GA_3, $CaCl_2$ and SA has the potential to control decaying incidence, prolong the storage life and preserve valuable attributes of post harvest tomato, presumably because of its effect on inhibition of ripening and senescence processes.

Key words: Fruit · Tomato · Post harvest treatment · Shelf life · Physicochemical

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important and widely cultivated vegetables in India and according to FAO [1] the annual production of tomato in India was 4,800 MT. There is increasing evidence that diet can play an important role in human health by providing important substances that increase the body defense system against several diseases. Tomato is a major contributor of carotenoids (especially lycopene), phenolics, vitamin C and small amounts of vitamin E in daily diets [2]. Results from the epidemiological studies showed that tomatoes and tomato products may have a protective effect against various forms of cancer, especially prostate cancer and cardiovascular diseases [3].

Since tomato is highly perishable it encounters several problems in its transportation, storage and marketing [4]. Owing to lack of information on appropriate post harvest treatments, packaging, temperature etc, the fruits not only lose their quality but also encounter a substantial post harvest loss. In tropical countries a loss of 20-50% [5] between harvesting, transportation and consumption of fresh tomato has been reported by Aworth and Olorunda [6]. Even though some research efforts have helped to increase the production of tomato to some extent, the purpose of obtaining maximum profit will be served only if the increased production is supplemented with the similar efforts to minimize the post harvest losses and enhance the shelf life. In the past, some efforts have been made in this direction by employing certain chemicals/plant growth hormones to hasten or delay ripening, to reduce losses and to improve and maintain the colour and quality by slowing down the metabolic activities of the fruit [7]. These chemicals are reported to arrest the growth and spread of micro organisms by reducing the shriveling which ultimately leads to an increased shelf life and maintain the marketability of the fruit for a longer period [7].

In view of the above reports, the present study has been undertaken to evaluate the potential of post harvest treatments of Gibberellic acid (GA_3), Calcium chloride ($CaCl_2$) and salicylic acid (SA) on the shelf life and physicochemical characteristics of tomato fruit during its storage. The reasons for selecting these chemicals for the present study are as follows:

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Gibberellins (GA_3) are a group of growth substances, which are known to retard ripening and senescence of fruits. The effect of GA_3 seems to be mainly on colour development, although other aspects of ripening processes are also affected [8].

The role of calcium chloride ($CaCl_2$) in the physiology of plant tissue is well established [9]. According to John [10], addition of calcium improves rigidity of cell walls and obstructs enzymes such as polygalcturonase from reaching their active sites, thereby retarding tissue softening and delaying ripening. Post harvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism thus extending storage life of fresh fruits [9].

Salicylic acid (SA), a common plant-produced phenolic compound, is an endogenous growth regulator, which participates in the regulation of physiological processes in plants. Exogenous application of salicylic acid may influence stomata closure [11], ion uptake and transport [12], inhibition of ethylene biosynthesis, transpiration and stress tolerance [13]. In addition, SA also shows some benefits for human health [13] for example, in prevention of cardiovascular disease. It is suggested that SA can be used for handling harvested fruits as a food additive as well as delaying some fruit ripening processes during post harvest storage.

MATERIALS AND METHODS

Collection of Sample: For the present study Himsona, one of very important commercial varieties of tomato, was selected and for this purpose partially ripened, orange yellow and uniform size of fresh fruit was freshly harvested from the local fields of Vallabh Vidyanagar, Gujarat, India.

Treatments and Experimental Design: Tomato fruits of uniform size were selected and they have been sorted out to eliminate bruised, punctured and damaged one. After removing the dust from the surface of these fruits, they were surface sterilized with sodium hypochlorite (500 ppm) for 10 minutes so as to reduce the fungal infection and air-dried. The post harvest treatments were carried out as per completely randomized block design with nine treatments (T) *viz*., (i) GA_3 0.1 % - (T1), (ii) GA_3 0.3 % - (T2), (iii) GA_3 0.5 % - (T3), (iv) $CaCl_2$ 0.5 % - (T4), (v) $CaCl_2$ 1 % - (T5), (vi) $CaCl_2$ 1.5 % - (T6), (vii) SA 0.1mM - (T7), (viii) SA 0.2mM - (T8), (ix) SA 0.4mM - (T9) and (x) a Control (treated with water) - (T10). Each of these treatments was given by dipping the fruits of each set comprising seven fruits in the treatment solution for 20 min. The treated tomato fruits were stored for experimentation in the laboratory with the average maximum and minimum temperature of it at 34±1°C and after 10 days of their storage in the laboratory these fruits as well as the fruits of control set were subjected for their following physicochemical analyses:

Physiological Loss of Weight (PLW) (%): The PLW of tomato fruit samples was calculated by considering the differences between initial weight and final weight of currently tested tomato fruits divided by their initial weight.

Decay or Rotting (%): The decay or rotting of the stored tomato fruits were determined by their visual observations. Decay percentage of tomato fruits was calculated as the number of decayed fruit divided by initial number of all fruits time 100.

Storage Life: The shelf life of these tomato fruits was calculated by counting the days required for them to attain the last stage of ripening, but up to the stage when they remained still acceptable for marketing [14].

pH, Titrable Acidity and Total Soluble Solid (TSS) of the Sample: The pH of the fruit samples was determined as per the method described by AOAC [15], while the titrable acidity (expressed as citric acid %) was determined by titrating 5-ml of juice with 0.1 N sodium hydroxide, using phenolphthalein as an indicator [16]. The TSS content of the fruit was determined by using refractrometer (Atago Co., Tokyo, Japan). Homogenous sample was prepared by blending the tomato flesh in blender. The sample was thoroughly mixed and a few drops were taken on prism of refractrometer and direct reading was taken by reading the scale in meter as described in AOAC [15].

Chemical Analysis: The reducing and non-reducing sugar contents were determined by following the dinitrosalicylic acid method, while the anthrone method was followed for the total soluble sugars [17]. The quantitative analysis of pigments such as total chlorophylls, total carotenoids and lycopene was carried out as per the methods described by Wang *et al.* [18].

Vitamin C (ascorbic acid) content was determined by using titrimetric method with the titration of filtrate against 2, 6- dichlorophenol indophenol and the results of vitamin C content were expressed as mg/100 g [19]. The method of Bray and Thorpe [20] was followed for determination of the quantity of total phenolics.

Statistical Analysis: All the presently performed analyses were carried out in triplicate and the standard deviation has been calculated. The experimental design was complete randomized design (CRD) with three replicates. Analysis of variance (ANOVA) was used to detect treatment effect. Mean separation was performed by using least significance difference (LSD) at the $p \leq 0.05$ level. The data were analyzed using Duncan's multiple range test (DMRT) [21].

RESULTS AND DISCUSSION

Effect on Weight Loss: Generally the weight loss of the tomato fruit increases progressively during their storage and this kind of weight loss continues till the fruit attains fully ripened stage. However, the weight of the currently tested fruits treated with the chemicals (GA_3, $CaCl_2$ and SA) is also found to get decreased, but in comparison with that of the fruits of control set the weight loss of chemically treated fruits is found to be lesser. After 10 days of storage the fruits of control set (treated with water) exhibited maximum weight loss (19.89%). Yaman and Bayoindirli [22] advocated that vapor–phase diffusion driven by a gradient of water vapor pressure at different locations as the reason for primary mechanism of moisture loss from fresh fruits and vegetables. Willis *et al*. [23] opined that the water loss can be reduced effectively by placing additional physical barriers between the produce and the surrounding air. A significant reduction ($p \leq 0.05$) in the weight loss by 67.31, 50.35 and 40.39% was observed in the first three treatments of GA_3, viz. T1, T2 and T3 respectively as compared with that of control set (Table 1). Perhaps, as Sudha *et al.* [7] postulated, the reduction of weight loss in the fruits treated with GA_3 might be due to its anti-senescent action. According to Wills *et al*. [23], during ripening of fleshy fruits changes in tissue permeability and cellular compartmentation occur. The GA_3 treatment which causes the decrease in the tissue permeability and there by reducing the rate of water loss, leads to delayed fruit ripening. Among the presently tested treatments, T1 (GA_3- 0.1%), T5 ($CaCl_2$- 1%), T6 ($CaCl_2$- 1.5%) and T9 (SA-0.4mM) are found to be more effective in reducing weight loss in tomato fruits. The percentage of weight loss in T1, T5, T6 and T9 treated fruits was 6.50, 6.64, 5.35 and 6.78, respectively, but the percentage of weight loss in control fruits reached to 19.89, which is almost 70 to 75% more weight loss (Table 1). Thus these results are in accordance with that of Lester and Grusak [24], who reported that calcium application was effective in terms of membrane functionality and integrity maintenance, with lower losses of phospholipids and proteins and reduced ion leakage which could be responsible for the lower weight loss found in calcium treated plums. Nanthawan and Kanlayanarat [25] also found that salicylic acid reduced weight loss during storage in Rambutan fruit.

Decay Percentage: Data summarized in Table 1 shows the changes of decay percentage values of treated and untreated tomato (control) fruits during their storage. Treatments significantly ($p \leq 0.05$) reduced the decay as compared to control sample. Fruits of T1, T5, T6 and T9 sets had the least deterioration percent (8.89%) followed with that of T2, T3 and T7 (11.11%) in comparison with that of untreated fruit (control) which showed the highest decay percentage (24.44) at the storage of 10 days period. The decay percentage of control sample, after 10 days of storage period, was approximately two to three times higher than that of the fruits treated with gibberellic acid, calcium chloride and salicylic acid. Calcium chloride treatment resulted in a reduction of decay percentage. Conway *et al.* [26] reported the changes in firmness as an indication of a degradation of the apple cell walls and consequent reduction in fruit quality and Conway *et al.* [26] further stated that the loss of firmness due to cell wall carbohydrate metabolism during storage has been associated with increased susceptibility to infection by fungal pathogens. The results of the present study reveals that the fruits treated with SA reduced the decay level, as reported earlier by Yiwei *et al.* [27] in sugar apple fruits.

Storage Life: The storage life of tomato fruits treated with T1 and T6 was found to get extended to the maximum duration of 18 days as compared to that of other presently tested treatments (Table 2). The treatment of 0.5%, 1% and 1.5% of $Cacl_2$ caused the extension of storage life of tomato fruits tested under the current study by 15, 17 and 18 days respectively, as compared (i.e. 10 days) to that of fruits of control set (Table 1). These results also supports the view of Cheour *et al*. [28] who reported that the application of calcium prolonged the storage life of strawberries, as measured by a delay in accumulation of sugars, decrease in organic acids, increase of color saturation index and mold development. Among the different concentrations of presently tested post harvest treatments with GA_3, the fruits treated with T1 exhibited longer storage life and reduced spoilage (Table 2). Rao Chundawat [29] advocated that post harvest dipping of fruits in GA_3 delayed the conversion of starch to sugars, reduced peroxidase activity and ethylene production.

Table 1: Effect of different post harvest chemical treatments and their concentrations on physiological loss of weight, decay and storage life of ~~the~~ tomato fruits after 10 days of storage at 34±1°C

Treatments	Physiological loss of weight (%)	Decay (%)	Storage life (days)
T1 (GA_3-0.1%)	6.50±1.35^{ab}	8.89±3.85^{a}	18
T2 (GA_3-0.3%)	9.87±0.91^{cd}	11.11±3.85^{a}	15
T3 (GA_3-0.5%)	11.85±0.47^{d}	11.11±7.70^{a}	14
T4 ($Cacl_2$-0.5%)	8.77±0.82^{bc}	13.33±6.67^{a}	15
T5 $Cacl_2$- 1%)	6.64±1.15^{ab}	8.89±3.85^{a}	17
T6 $Cacl_2$-1.5%)	5.35±2.26^{a}	8.89±3.85^{a}	18
T7(SA-0.1mM)	11.56±1.58^{d}	11.11±7.70^{a}	13
T8 (SA- 0.2mM)	9.95±0.28^{cd}	13.33±6.67^{a}	14
T9 (SA- 0.4mM)	6.78±0.85^{ab}	8.89±3.85^{a}	17
T10 (Control)	19.89±2.17^{e}	24.44±3.85^{b}	10
LSD (5% level)	2.2856.00	9.2700.00	

Means with the same letters within a column are not significantly different at p≤.05 using LSD

Each value is the mean for three replicates

Table 2: Effect of different post harvest chemical treatments and their concentrations on pH, titrable acidity and total soluble solids of ~~the~~ tomato fruits after 10 days of storage at 34±1°C

Treatments	pH	Titrable acidity (%)	Total soluble solids (°Brix)
T1 (GA- 0.1%)	4.20±0.003^{a}	0.62±0.007^{g}	8.3±0.035^{a}
T2 (GA- 0.3%)	4.21±0.002^{b}	0.59±0.014^{f}	8.4±0.036^{b}
T3 (GA- 0.5%)	4.23±0.005^{c}	0.57±0.007^{cde}	8.6±0.032^{c}
T4 (CA- 0.5%)	4.26±0.004^{e}	0.52±0.012^{b}	8.8±0.020^{e}
T5 (CA- 1%)	4.23±0.005^{c}	0.56±0.012^{cd}	8.6±0.037^{d}
T6 (CA- 1.5%)	4.21±0.003^{b}	0.58±0.006^{ef}	8.5±0.051^{b}
T7(SA-0.1mM)	4.25±0.002^{d}	0.52±0.007^{ab}	8.7±0.020^{e}
T8 (SA- 0.2mM)	4.23±0.001^{c}	0.55±0.006^{c}	8.6±0.035^{d}
T9 (SA- 0.4mM)	4.21±0.003^{b}	0.58±0.005^{def}	8.5±0.010^{c}
T10 (control)	4.33±0.002^{f}	0.50±0.009^{a}	9.32±0.03^{f}
LSD (5% level)	0.0061	0.0165	0.0563

Means with the same letters within a column are not significantly different at p≤0.05 using LSD

Each value is the mean for three replicates

The fruits treated with SA also showed extended storage life compared to that of water treated fruits and among them T9 fruits exhibited longer storage life i.e. 17 days (Table 1). Further Lam *et al*. [30] stated that SA as an antitranspirant chemical can retard moisture loss-associated pericarp browning of fruits. Senescent changes resulting to losses in physicochemical changes and nutritional qualities can also be inhibited. Consequently, fruit storage life could be markedly prolonged.

pH and Titrable Acidity: The pH of the fruit pulp of treated fruits was found relatively in lesser range (i.e. 4.20- 4.26) as compared to the fruits of control set having higher pH (4.33) after 10 days of their storage. The treatments and their interactions had highly significant (p≤0.05) effect on pH value. The maximum pH value among the treated fruits was observed in T4 (4.26), followed byT7 (4.25), T3, T5 and T8 (4.23), T2, T6 and T9 (4.21) and least in T1 (4.20) (Table 2). All these treatments exhibited comparatively lower pH as compared to that of the fruits of control set (Table 2). In comparison, the pH of the chemically treated fruits was found to be lower than that of the pH of the fruits of control set, which might be due to the differences in the modified atmosphere created by different types of treatments. The fluctuations of pH might be due to the variations in titratable acidity or temperature of storage and the decline of acidity is attributed due to increased activity of citric acid glyoxylase during ripening or reduction in acid content may be due to their conversion into sugars and further utilization in metabolic process during storage [31]. The treatment of calcium at the concentration of 0.5, 1 and 1.5 % proved to be better in maintaining low pH significantly (p≤0.05), as compared with untreated fruits. So in this respect the results of the present study showed

that increasing calcium concentration applications cause significant effect on pH. The findings of the present study are, therefore, consistent with the findings of Andrea *et al*. [32] who reported that the post harvest application of calcium chloride in strawberry fruits reduced the pH of fruits during their storage.

As Bhattarai and Gautam [33] stated that during storage the fruit itself might utilize the acids so that the acid in the fruits during storage periods decrease. This view has been further substantiated by Ramana *et al.* [34] by citing the reasons that the change in total titrable acids during storage was mainly due to the metabolic activities of living tissues during which depletion of organic acids takes place. Further, Ramana *et al.* [34] also reported that decrease in total acidity and increase in total sugars and TSS during storage at room temperature. The results of the present study indicate that all the treatments and their interactions cause highly significant ($p \leq 0.05$) differences on the percent titratable acidity of tomato from each other. The statistical analysis of the data obtained from the present study indicate that the maximum titratable acidity was observed in T1 (0.62%) followed by T2 (0.59%), T6 and T9 (0.58%), T3 (0.57%), T5 (0.56%), T8 (0.55%) and T4 and T7 (0.52%) as compared to control T10 (0.50%) during storage (Table 2). Perhaps the retention of acidity in calcium treated fruits might be due to reduction in metabolic changes of organic acid into carbon dioxide and water. These results are in agreement with those of Ibrahim [35] who showed higher retention of acidity in the calcium chloride treated apricot during its storage. Gibberellic acid treatment also retarded the decrease of titrable acidity as compared to that of the fruits of control set. Cheour *et al*. [28], while reporting that the quantity of organic acids expressed as citric acid decreased in strawberry fruits during storage, stated that calcium causing inhibition of enzyme activity could explain the delay in the use of organic acids in the enzymatic reactions of respiration.

Effect on Total Soluble Solids: The significant ($p \leq 0.05$) changes in the TSS values of treated and untreated (control) tomato fruits during their post harvest storage which are presented in Table 2 show that a control sample without treatment had significantly highest level of TSS value (i.e. 9.32%) after 10 days of storage period. The TSS values of tomato fruit treated with GA_3, $Cacl_2$ and SA treatments were lower than that of control samples treated with water. The reduction in the TSS of calcium treated tomato fruit was probably due to slowing down of respiration and metabolic activity, hence retarding the ripening process. In this regard the view of Rohani *et al.* [36] is noteworthy that the slower respiration also slows down the synthesis and use of metabolites resulting in lower TSS due to the slower change from carbohydrates to sugars. Our results are in line with an earlier report by Cheour *et al*. [28] who reported that the concentration of free sugars progressively increased with storage and that this increase was quite markedly delayed by calcium treatment. Cheour *et al*. [37] also stated that the application of calcium increased fruit calcium content and influenced several post harvest senescence changes involving free sugars, organic acids, anthocyanin content and texture of fruits. Among all the presently tested treatments, the fruits treated with GA_3 (T1) showed least values of TSS (8.3%). Ahmed and Tingwa [38] also reported significantly reduced TSS value in GA_3 treated banana fruit. Besides, the results of the present study also shows that SA treatment also lowers the TSS value as compared to that of control fruits, which indicating that SA delays fruit softening process as well as starch degradation. Therefore, as reported by Yiwei *et al.* [27], a lower decay rate in the fruits tested under current study was observed.

Effect on Sugar Content: The breakdown of polysaccharides into water soluble sugar might be a reason for an increase in the sugar content. The findings of Matto *et al.* [39] also indicated that starch is completely hydrolyzed into soluble sugar such as glucose, fructose and sucrose as ripening progresses. The treatments of GA_3, $Cacl_2$ and SA are found to cause lowering of total sugars, reducing sugars and non reducing sugars than that of fruits of control set (Table 3). Among all the presently treated fruits, the fruits of T1, T6 and T9 sets have shown significantly ($p \leq 0.05$) lower amount of total sugar content compared to that of fruits of other sets. The GA_3 treated fruits i.e. T1 (0.51 mg/g), T2 (0.71 mg/g) and T3 (0.68 mg/g) yielded less amount of total sugars as compared to the fruits of control set (0.88 mg/g) (Table 3). Similar results have been reported earlier by Abo Aziz *et al.* [40] who noticed that the percentage of total sugars was significantly affected by different treatments from GA_3. In contrast, the fruits of control set gave higher yield of reducing sugars and a similar kind of finding was observed by Abo-El-Ez *et al*. [41]. The effect of GA_3 seems to be mainly on colour development, although other aspects of ripening processes are also affected. Ahmed and Tingwa [38] advocated

Table 3: Effect of different post harvest chemical treatments and their concentrations on reducing sugars, non reducing sugars and total sugars of ~~the~~ tomato fruits after 10 days of storage period at 34±1°C

Treatments	Reducing sugars (mg/g)	Non reducing sugars (mg/g)	Total sugars (mg/g)
T1 (GA_3-0.1%)	0.33±0.009^{a}	0.18±0.004^{a}	0.51±0.009^{a}
T2 (GA_3-0.3%)	0.50±0.007^{h}	0.21±0.002^{cd}	0.71±0.009^{g}
T3 (GA_3-0.5%)	0.45±0.003^{g}	0.24±0.001^{fg}	0.68±0.003^{f}
T4 ($Cacl_2$-0.5%)	0.39±0.013^{cd}	0.23±0.002^{g}	0.62±0.014^{d}
T5 $Cacl_2$- 1%)	0.39±0.008b^{c}	0.21±0.002^{e}	0.60±0.010^{c}
T6 $Cacl_2$-1.5%)	0.38±0.005^{b}	0.20±0.002^{c}	0.58±0.004^{b}
T7(SA-0.1mM)	0.42±0.003^{f}	0.23±0.002^{f}	0.65±0.005^{e}
T8 (SA- 0.2mM)	0.40±0.003^{e}	0.21±0.001^{de}	0.61±0.004^{d}
T9 (SA- 0.4mM)	0.39±0.004^{d}	0.19±0.002^{b}	0.58±0.007^{c}
T10 (Control)	0.53±0.005^{i}	0.35±0.003^{h}	0.88±0.009^{h}
LSD (5%)	0.0122.000	0.0046.000	0.0143.000

Means with the same letters within a column are not significantly different at $p \leq 0.05$ using LSD

Each value is the mean for three replicates

Table 4: Effect of different post harvest chemical treatments and their concentrations on total chlorophylls, carotenoids, lycopene, ascorbic acid and total phenols of the tomato fruit after 10 days of storage at 34±1°C

Treatments	Total chlorophylls (µg/g)	Carotenoids (µg/g)	Lycopene (µg/g)	Ascorbic acid (mg/100g)	Total phenols (mg/g)
T1 (GA_3-0.1%)	6.19±0.76^{cd}	32.71±0.49^{b}	22.35±0.35^{a}	14.76±1.98^{d}	0.30±0.0053^{g}
T2 (GA_3-0.3%)	5.67±0.15^{bc}	46.20±1.4^{f}	23.51±0.43^{b}	11.28±0.75^{bc}	0.24±0.0047^{f}
T3 (GA_3-0.5%)	5.42±0.46^{b}	48.04±0.54^{g}	31.80±0.47^{e}	10.85±0.75^{abc}	0.16±0.0031^{b}
T4 ($Cacl_2$-0.5%)	4.53±0.32^{a}	43.03±0.42^{e}	24.88±0.50^{c}	9.55±0.75^{ab}	0.16±0.0023^{b}
T5 $Cacl_2$- 1%)	5.47±0.32^{b}	39.53±0.72^{d}	25.21±0.31^{c}	9.77±0.65^{abc}	0.19±0.0029^{c}
T6 $Cacl_2$-1.5%)	6.48±0.45^{d}	36.14±0.42^{c}	22.42±0.30^{a}	11.07±1.72^{abc}	0.25±0.0024^{f}
T7(SA-0.1mM)	5.36±0.15^{b}	42.82±0.33^{e}	31.96±0.46^{e}	9.24±0.12^{a}	0.16±0.0028^{b}
T8 (SA- 0.2mM)	5.50±0.20^{bc}	41.95±0.59^{e}	32.20±0.19^{e}	9.34±0.11^{ab}	0.19±0.0060^{d}
T9 (SA- 0.4mM)	5.87±0.11^{bcd}	29.35±1.35^{a}	28.57±0.45^{d}	11.58±0.11^{c}	0.20±0.0041^{e}
T10 (Control)	5.25±0.28^{b}	52.27±0.88^{h}	33.14±0.52^{f}	9.11±1.30^{a}	0.15±0.0028^{a}
LSD (5%)	0.6354.00	1.3703.00	0.7071.00	1.7679.00	0.0067.00

Means with the same letters within a column are not significantly different at $p \leq 0.05$ using LSD

Each value is the mean for three replicates

that GA_3 delays chlorophyll degradation and fruit softening and decreases sugar accumulation [e.g. TSS and sugar/ acid ratio] in banana. However, the presently studied tomato fruits treated with $Cacl_2$ and SA showed reduction in sugar accumulation and these findings are in accordance with the report of Cheour *et al.* [37] and Yiwei *et al.* [27], respectively.

Pigments: The data obtained pertaining to the total chlorophylls, total carotenoids and lycopene as affected by the treatments tested under current study are presented in Table 4. The quantitative analysis of photosynthetic pigments indicates that they occur more in the chemically treated fruits. In contrast, control fruit exhibit weaker stimulation on total chlorophyll accumulation. All the treatments, except T4, showed significantly ($p \leq 0.05$) more amount of total chlorophylls compared to that of control set (Table 4). Carotenoids act as important biological compounds, that they are widely distributed in fruits and vegetables. They have received considerable attention in recent years because of their possible role in the prevention of chronic diseases [42]. Lycopene is a phytonutrient and an antioxidant and this pigment is responsible for the characteristic deep red colour of ripe tomatoes and their products [43]. More accumulation of carotenoids and lycopene in the fruits of control set is found to be statistically significant ($p \leq 0.05$) (Table 4), while the chemically treated fruits showed lesser and slow accumulation. Application of GA_3 delayed the degradation of chlorophylls (degreening) and the development of carotenoids. Similar kinds of findings were reported in mango fruit by Khader *et al.* [44]. Application of SA on the presently studied tomato fruits is found to cause more accumulation of chlorophyll. These results are in agreement with that of Türkyýlmaz *et al.* [45] who reported that foliar spray with

salicylic acid increased Chl. a, Chl. b and other photosynthetic pigments in bean plants. Moreover, the treatment of SA also delayed the accumulation of carotenoid content in the fruits of tomato. A similar kind of phenomenon was noticed in navel orange fruit by Renhua *et al*. [46].

Ascorbic Acid and Total Phenols: An increase in ascorbic acid content in fruit is thought to be an indication that the fruit is still in the ripening stage, while a decrease indicates a senescent fruit [47]. In addition, Miller and Rice Evans [48] reported that phenolic substances have been found to play a protective effect on the ascorbic acid. The presence of phenolics in the fruit cells may help to maintain the ascorbic acid content. The level of ascorbic acid was found to be maintained with post harvest applications of GA_3, CA and SA and its level was significantly higher ($p \leq 0.05$) in T1 treated fruits i.e. 14.76 mg/100g. During storage the tomato fruits treated with T1 (GA_3-0.5%) exhibited higher levels of ascorbic acid in contrast with that of other treatments and the fruits of control set (Table 4). In comparison to control fruits treated with water, all the treatments tested under current study have shown higher impact on the ascorbic acid content. The results obtained from the present study indicate that the GA_3, CA and SA treatments were beneficial in retarding degradation of ascorbic acid content of tomato fruits during their storage. The retention of ascorbic acid in the currently analyzed tomato fruits was maximum in T1 (14.76 mg/100g) followed by T9 (11.58 mg/100g), T2 (11.28 mg/100g), T6 (11.07 mg/100g), T3 (10.85 mg/100g), T5 (9.77 mg/100g), T4 (9.55 mg/100g), T8 (9.34 mg/100g), T7 (9.24 mg/100g) and T10 (9.11 mg/100g) (Table 4). This pattern of retention of ascorbic acid, according to Mapson [49], might be due to the lowering of respiration of fruits or oxidation of ascorbic acid content of the treated fruits with CA which had reduced the loss of ascorbic acid content. The SA treated fruits exhibited higher retention of ascorbic acid as compared to that of control set, but among the SA treatments T9 exhibited highest amount (11.58 mg/100g) of ascorbic acid. Renhua *et al.* [46] reported that application of SA was found to be effective in reducing the rate of respiration and ethylene production and yielding higher amount of ascorbic acid. Further, Lam *et al.* [30] stated that the SA as antitranspirant chemical, which can retard the moisture loss associated with pericarp browning of fruits. Besides, senescent changes resulting to losses in physicochemical changes and nutritional qualities can also be inhibited; consequently fruit storage life could be markedly prolonged. According to the Renhua *et al.* [46] exogenous SA pretreatment could change the antioxidant system and maintain the nutritional value of fruits and vegetables, which have a higher ability to withstand oxidation injuries. During the course of present study, it was found that SA treatment increases the content of ascorbic acid during the storage period. This kind of increase in ascorbic acid content may be explained it as connected with metabolic processes.

It has long been recognized that naturally occurring substances in the fruits and vegetables have antioxidant activity. Among these substances, the phenolics are widely distributed and have the ability to scavenge free radicals, superoxide and hydroxyl radical by a single-electron transfer [50]. During the course of present study, after 10 days of storage tomato fruits treated with T1 (0.30 mg/g) and T6 (0.25 mg/g) and T2 (0.24 mg/g) exhibited maximum phenolic content, while least of it (0.15 mg/g) in the fruits of control set (Table 4). Similarly, Rensburg and Enqelbrecht [51] reported in avocados fruits that calcium compound treatments resulted in suppression of respiration and high phenolic content. Treatments with GA_3 and CA might have delayed senescence which resulted in maintenance of fruit health in storage. More or less similar kind of results was reported by Kumar *et al*. [52] in jujube fruits. The phenolic contents of SA treated tomato fruits were found to get increased and the higher concentration of SA (i.e. 0.4mM) treatment showed a positive effect on them. The profiling of phenolics showed fluctuations in their quantity, indicating that their metabolism was affected by SA treatment. Yao and Tian [53] demonstrated that SA stimulates phenylalanine ammonia lyase activity with consequent production of the main phenolic compounds and the synthesis of new polyphenolic substances in sweet cherry fruit.

CONCLUSION

The obtained results indicated that gibberellic acid, calcium chloride and salicylic acid play a very effective role in controlling the weight loss, decay percentage and other compositional changes such as pH, titratable acidity, total soluble solids, total sugars, total chlorophylls, carotenoids, lycopene, ascorbic acid and total phenols of tomato stored at room temperature. These treatments have delayed the ripening process more effectively and with a minimum quality loss, as compared to the control sample which had greater compositional changes with maximum quality loss during storage at

ambient temperature. The shelf life of tomato could be extended upto 18 days without excessive deterioration in quality by treating the fruits with gibberellic acid, calcium chloride and salicylic acid. Among all the tested treatments, GA_3-0.1%, $Cacl_2$-1.5% and SA-0.4mM benefits storage life capacity and maintains quality characteristics as compared to the fruits of control set. Thus it may be concluded that the post harvest chemical treatments selected for the present study have the potential to extend the shelf of tomato while retaining its nutritional quality.

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