**Philippine Journal of Science**
150 (1): 335-349, February 2021
ISSN 0031 - 7683
Date Received: 27 Aug 2020

# Effect of Different Concentrations of the Gibberellic Acid and Calcium Chloride Dipping on Quality and Shelf-life of Kochoro Variety Tomato

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**Tomato is a highly perishable horticultural produce; post-harvest management is very crucial to maintain the quality and to extend shelf life. In view of this, the present research was carried out to determine the effect of gibberellic acid ($GA_3$) (0.075, 0.1, and 0.125%) and calcium chloride ($CaCl_2$) (1, 1.5, and 2%) treatments on quality and shelf life of tomato (Kochoro variety) in two (green matured and pink) ripening stages. The experiment was carried out involving two factors (treatment and ripening stage) arranged in a completely randomized design (CRD) with three replications. The treated fruits were stored at room temperature and the data on quality and shelf life was collected once in every 5 d. The data were analyzed using SAS version 9.8 for analysis of variance (ANOVA) and correlation. The mean temperature and relative humidity throughout the storage period were reported as 24.67 °C and 55.48%, respectively. The results of the study showed that the least color changes (1.16) and (1.38) were observed for the fruits treated with 1.5% $CaCl_2$ in green mature (20 d of storage) and pink (15 d of storage) stages. Treatments of 0.1% $GA_3$ and 1.5% $CaCl_2$ effectively maintained the firmness of tomato fruits in green matured (0.7 kg/cm$^2$) and pink (0.5 kg/cm$^2$) stages by 20 d of storage duration. Treatment of 1% and 1.5% of $CaCl_2$ on green matured tomato samples reported only 20% of the decay by 20 d of storage; however, control samples reported 60% of decay. Finally, from this study, it was concluded that postharvest treatments are significant in maintaining the quality and shelf life of the tomatoes in the green stage up to 20 d. Treatment with 1.5% $CaCl_2$ and 0.125% $GA_3$ is effective to prolong the storage life and quality of pink tomato; in the case of the green mature stage, treatment with 0.125% $GA_3$ showed maximum shelf life.**

Keywords: calcium chloride, gibberellic acid, post-harvest loss, shelf life, tomato

## INTRODUCTION

Tomato (*Solanum lycopersicum* L.) possesses a very important role in the human diet (Canene-Adams *et al.* 2005) as it is composed of 90% water, 5–7% soluble and insoluble solids, considerable amounts of organic acids, vitamins (A and C), and minerals (Ca, Fe, Mg, and K) (Pinela *et al.* 2012). Tomato is appreciated for its high amount of lycopene (Toor and Savage 2005), many scientific reports established the health benefits of the lycopene (Story *et al.* 2010).

Tomato is cultivated worldwide in tropical, subtropical, and temperate climates (Naika *et al.* 2005). In 2018, global tomato production reached 182.256 M tons, cultivated in 4.76 M ha of land (FAO 2018). Similarly, in the year 2017, tomato production in Ethiopia was reported at 43816 tons from 7089 ha of land (FAO 2018). Tomato is a climacteric fruit, having respiratory peak

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during the ripening process (Cara and James 2008). Being a climacteric and perishable vegetable, tomatoes have a very short shelf-life and huge losses were reported in the tomato value chain (Arah *et al.* 2016). Postharvest losses in fresh horticulture produce reported in range of 2–20% in developed countries and from 24–40% in developing countries, as in the case of Ethiopia (Kasso and Bekele 2018). Higher levels of losses resulted in higher prices for fresh produce and farmer are facing problems of financial losses. Moreover, the higher price of produce directly leads to problems in food security. Thus, the reduction of post-harvest losses in perishable crops is very important to provide financial security to farmers and to achieve food security in developing countries (Kader 2005).

During post-harvest handling, fruit and vegetables deteriorate due to the many factors; for example, microorganisms change physiological properties due to ripening and mishandling (Fári *et al.* 2014). Similarly, various factors such as physical injuries, high storage temperatures, variations in relative humidity, and high ethylene presence in the storage environment are major factors that reduce the shelf life of tomatoes. Recently, good agricultural practices have been applied by farmers in Ethiopia due to modern cultivation; however, this does not translate into profit as most yields are lost after harvest (Emana *et al.* 2015).

Therefore, several postharvest interventions are needed to maintain quality and extend the shelf life of tomatoes. Some researchers in Ethiopia managed to succeed in extending the shelf life of tomatoes through low-cost storage methods like the application of edible coatings (*e.g.* chitosan, wax) (Zekrehiwot *et al.* 2017), coating with plant extracts (Fufa *et al.* 2019), use of low-cost storage structures (Esa *et al.* 2015), and drying (Yusufe *et al.* 2017a, b). However, these methods are not adopted by Ethiopian farmers due to cost limitations (in constructing storage structures), non-availability of coating materials (*e.g.* chitosan, plant extracts), and process difficulties. Thus, farmers are looking for an easy process to extend the shelf life such as dipping. In contrast, in developed countries, advanced methods like cold storage, modified atmospheric packing (Fagundes *et al.* 2015), controlled atmospheric packaging (Majidi *et al.* 2014), and application of chemical preservatives (*e.g.* 1-MCP) (Guillen *et al.* 2007) are available for shelf-life extension of tomato. However, these techniques require high investment cost, energy, and technology, all of which are difficult to facilitate in underdeveloped countries like Ethiopia. The $CaCl_2$ treatments are considered a simple and economical processing aid (Hussain *et al.* 2011). Researchers reported that calcium treatment contributes to cell wall integrity, maintains firmness, delays softening, delays membrane lipid catabolic processes, effectively controls postharvest decay caused by different molds, inhibits ethylene production, and lowers the respiration rates (Serrano *et al.* 2004). Serrano *et al.* (2004) also reported the ability of $GA_3$ to inhibit chlorophyll loss in fruits, effectively delay fruit ripening, reduce net change in fruit color and respiration rate, and delay the degradation of ascorbic acid and the activities of enzymes like amylase and peroxidase.

However, treatment of tomato with $CaCl_2$ (Pila *et al.* 2010) and $GA_3$ (Pila *et al.* 2010; Srividya *et al.* 2014; Sharma *et al.* 2018) was practiced in different parts of the world. However, these treatments in Ethiopian tomato varieties are not studied well. In view of the above, the objective of this study was conducted to determine the effect of $GA_3$ and $CaCl_2$ in different concentrations on the quality and shelf life of tomato (Kochoro variety) in green mature and pink stages.

## MATERIAL AND METHODS

### Collection and Processing of Tomato

Kochoro variety tomatoes were collected from AARC (Adet Agricultural Research Center) in Weramit sub-center, Bahir Dar City, Ethiopia in pink and green mature stages (Skolik *et al.* 2019). Manual harvesting of fruits was performed during early morning hours (06:00–07:00 AM) and fruits were selected and cleaned with distilled water. Twenty (20) uniform-sized fruits were used for each treatment according to the experimental design. About 100 kg of fruits (green mature and pink stages) were used in this study.

### Experimental Design

The experiment was designed in a two-factor design arranged in CRD, the first factor being the treatment with six levels ($GA_3$ 0.075%, $GA_3$ 0.1%, $GA_3$ 0.125%, $CaCl_2$ 1%, $CaCl_2$ 1.5%, $CaCl_2$ 2%) and the second factor being the maturity with two levels (green matured and pink). The experiment was repeated three times and two controls (untreated green matured and untreated pink stage tomatoes) were maintained. The total experimental runs conducted in this study were 38. The observation on the quality and shelf life was recorded once in a five-day interval. From the literature, the recommended level was 1.5% $CaCl_2$ and 0.1% $GA_3$ for other varieties of tomato (Pila *et al.* 2010). However, to determine the best concentration of $GA_3$ and $CaCl_2$ for the Kochoro variety in this study, the treatment concentrations were used below and above the recommended levels.

### Solutions Preparation and Experimental Setup:

According to the experimental design, concentrations of $GA_3$ in 0.075, 0.1, and 0.125% plus $CaCl_2$ in 1, 1.5, and 2% were prepared, following the methods of Porat *et al.* (2001) and Pila *et al.* (2010), respectively. Three liters (3 L) of each concentration solution was prepared individually for each treatment. Twenty (20) tomato fruits for each treatment were dipped in the prepared solution and allowed to rest for 15 min. Further, tomatoes were separated from the dipped solution and surface-dried at room temperature. All 20 treated and dried tomatoes were stored in tray-type open carton boxes arranged in a single layer. These boxes were kept at room temperature with natural airflow and ventilation.

**Data Collection**

The following quality parameters were analyzed once in every five-day interval.

Temperatures were measured using HOBO® Temp Data Logger (model: UX100-001; range: –20 to 70 °C); similarly, relative humidity was measured using HOBO® Temp/RH 2.5% Data Logger (model: UX100-011). The color change was analyzed according to the method described by Batu (2004) and Khairia *et al.* (2015). Fruit firmness was measured by the method of Kitinoja and Hussein (2005) by using a texture analyzer. Weight loss was determined by taking the initial and final weights of fruit samples in each storage duration interval (Pila *et al.* 2010). Total soluble solids (TSS) content of the tomato fruit juice was determined by using a handheld refractometer, whereas TA was determined through the titration method (Gerefa *et al.* 2015). Lycopene and β-carotene content were determined by spectroscopy by using the method of Nagata and Yamashita (1992). The pH of tomato samples was determined by the method described by Gerefa *et al.* (2015). The decay or rotting of the stored tomato fruits was determined in each interval by visual observations by the method of Pila *et al.* (2010). However, the clear procedures used for different parameters are provided in the Appendices section.

**Statistical Data Analysis**

The collected data were subjected to ANOVA using SAS software version 9.2. Treatments showed significant differences in ANOVA were subjected to the mean separation using least significant difference (LSD) at 5% significance level. To evaluate the relationships among quality parameters of tomatoes, a correlation analysis was performed (Montgomery 2012).

## RESULTS AND DISCUSSIONS

**Temperature and Relative Humidity**

The average room temperature recorded on the initial day was 24.6 °C; on Days 5, 10, 15, and 20, it was recorded as 24.5, 27.0, 25.1, and 28.8 °C, respectively. The average daily relative humidities on the initial day and on Days 0, 5, 10, 15, and 20 were observed as 54.4, 60.8, 56.6, 52.8, and 52.8%, respectively. The identified temperature and relative humidity in this study varied from the recommended conditions for the best preservation of tomatoes (19–21 °C, 90–95%) (Lana *et al.* 2005).

The metabolic activity of tomatoes continues even after harvesting as fruits reach the peak ripened (red) stage in storage, which continues until it reaches the level of sensuousness (Toor and Savage 2006).

**Effects of $CaCl_2$ and $GA_3$ Dipping on Color Change**

The color change values of dipped and control green mature tomato samples were statistically non-significant in the initial, 10$^{th}$, and 15$^{th}$ day of the storage period; other storage durations on the 5$^{th}$ and 20$^{th}$ day was highly significant ($p < 0.001$) (Table 1). In the case of pink stage tomatoes, color change in the 5$^{th}$, 10$^{th}$, and 15$^{th}$ days showed high statistical significance ($p < 0.001$). The least color change was observed in both $CaCl_2$ and $GA_3$ treatments compared to control. In the case of green matured tomatoes on the 5$^{th}$ day of storage, less color change was observed (–0.36) for 2% $CaCl_2$ among all treatments. A rapid color change was observed in the control (1.31) samples of green matured tomato fruits stored for 20 d, but all the $CaCl_2$ treatments and the 0.125% $GA_3$ treatment showed a potentially slower color change in green matured tomatoes. In the pink stage tomatoes, a higher color change was observed in control samples (1.12); in contrast, the lowest was observed in the 0.075% $GA_3$ treatment at 5 d of storage. Untreated tomatoes had faster color change (1.87); among treated samples, those with 0.1% $GA_3$ showed the lowest (1.80) color change at 20 d of the storage period; however, the data was not statistically significant. As ripening proceeds, chlorophyll degrades with the formation of color pigments like carotenes and lycopene (Delgado-Vargas *et al.* 2000).

The slower color change in tomato samples dipped in $GA_3$ was attributed to the antagonistic activity to ethylene, as $GA_3$ prevents chlorophyll destruction caused by ethylene (Weiss and Ori 2007). $GA_3$ has a higher affinity towards ethylene receptor sites than ethylene; therefore, $GA_3$ competes with ethylene receptor sites and inhibits the ethylene action in the fruit ripening process (Singh *et al.* 1988). In the case of the calcium treatment, $Ca^{2+}$ ions can form salt-bridge cross-links with pectin molecules; this makes the cell wall inaccessible to enzymes for the softening process (ripening) (Daundasekera *et al.* 2015). In both treatments, the color change was slower; it may be attributed to the treated compounds that inhibit the ripening process. The results of the present study were in agreement with the findings of Flores *et al.* (2012) and Okolie and Sanni (2012).

**Table 1.** Effect of $CaCl_2$ and $GA_3$ dipping on color change and firmness of green matured and pink stage tomatoes stored for 20 d.

| Treatment | Level (%) | Color change | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Storage (d) | | | | | Pink stage Storage (d) | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| | 1 | -0.26 | $-0.38^{abc}$ | 1.07 | 1.31 | $1.27^{b}$ | 0.45 | $1.04^{d}$ | $1.22^{bc}$ | $1.49^{d}$ | **1.84** |
| **$CaCl_2$** | 1.5 | -0.26 | $-0.41^{cd}$ | 1.04 | 1.24 | $1.27^{b}$ | 0.47 | $1.05^{dc}$ | $1.26^{bc}$ | 1.38 | **1.87** |
| | 2 | -0.26 | $-0.36^{a}$ | 0.97 | 1.15 | $1.27^{b}$ | 0.45 | $1.08^{bc}$ | $1.24^{c}$ | $1.47^{c}$ | **1.89** |
| | 0.125 | -0.26 | $-0.41^{d}$ | 1.01 | 1.27 | $1.27^{b}$ | 0.45 | $1.04^{d}$ | $1.26^{bc}$ | $1.67^{b}$ | **1.87** |
| **$GA_3$** | 0.1 | -0.28 | $-0.37^{a}$ | 1.14 | 1.20 | $1.52^{a}$ | 0.45 | $1.05^{dc}$ | $1.25^{bc}$ | $1.56^{bc}$ | **1.80** |
| | 0.075 | -0.27 | $-0.39^{bcd}$ | 1.09 | 0.91 | $1.53^{a}$ | 0.45 | $1.09^{ab}$ | $1.51^{ab}$ | $1.49^{c}$ | **1.82** |
| **Control** | 0 | -0.28 | $-0.37^{ab}$ | 1.37 | 1.41 | $1.73^{a}$ | 0.47 | $1.12^{a}$ | $1.66^{a}$ | $1.81^{a}$ | **1.87** |
| **LSD (5%)** | | 0.027 | 0.025 | 0.58 | 0.71 | 0.24 | 0.03 | 0.03 | 0.35 | 0.15 | **0.20** |
| **CV (%)** | | 6.35 | 0.08 | 3.61 | 4.51 | 0.05 | 3.460 | 0.020 | 1.25 | 0.65 | **9.21** |
| **Significance level** | | ns | *** | ns | ns | *** | ns | *** | *** | *** | **ns** |

| Treatment | Level (%) | Firmness ($kg/cm^2$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Storage (d) | | | | | Pink stage Storage (d) | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| | 1 | 1.19 | 0.99 | $1.063^{ab}$ | $0.68^{bc}$ | $0.62^{ab}$ | 0.72 | 0.69 | $0.65^{a}$ | $0.47^{bc}$ | **$0.41^{bc}$** |
| **$CaCl_2$** | 1.5 | 1.19 | 1.20 | $1.29^{a}$ | $0.88^{a}$ | $0.63^{ab}$ | 0.83 | 0.79 | $0.71^{a}$ | $0.68^{a}$ | **$0.56^{a}$** |
| | 2 | 1.21 | 1.02 | $0.98^{abc}$ | $0.68^{bc}$ | $0.51^{bc}$ | 0.68 | 0.69 | $0.69^{a}$ | $0.56^{ab}$ | **$0.49^{ab}$** |
| | 0.125 | 1.20 | 0.81 | $1.09^{a}$ | $0.75^{b}$ | $0.52^{bc}$ | 0.70 | 0.68 | $0.51^{b}$ | $0.41^{bc}$ | **$0.37^{bc}$** |
| **$GA_3$** | 0.1 | 1.18 | 1.26 | $1.07^{a}$ | $0.88^{a}$ | $0.70^{a}$ | 0.69 | 0.74 | $0.65^{a}$ | $0.36^{c}$ | **$0.30^{c}$** |
| | 0.075 | 1.22 | 1.04 | $1.13^{a}$ | $0.69^{bc}$ | $0.53^{bc}$ | 0.77 | 0.68 | $0.69^{a}$ | $0.32^{d}$ | **$0.30^{d}$** |
| **Control** | | 1.19 | 1.02 | $0.78^{bc}$ | $0.587^{c}$ | $0.42^{c}$ | 0.79 | 0.75 | $0.49^{b}$ | $0.31^{dc}$ | **$0.24^{d}$** |
| **LSD (5%)** | | 0.03 | 0.03 | 0.46 | 0.31 | 0.13 | 0.15 | 0.261 | 0.23 | 0.17 | **0.192** |
| **CV (%)** | | 1.3 | 1.39 | 2.23 | 3.13 | 2.92 | 5.47 | 3.53 | 2.13 | 6.88 | **0.7481** |
| **Significance level** | | **ns** | **ns** | **ns** | *** | *** | *** | **Ns** | ** | *** | ** |

Means followed by the same letters(s) within the same column are not significantly different at 5% level of significance; ***highly significant, **significant, ns – non-significant

### Effects of $CaCl_2$ and $GA_3$ Dipping on Firmness

$CaCl_2$ and $GA_3$ dipping imparted a highly significant ($p < 0.001$) difference in firmness at 15 and 20 d of storage in green matured tomatoes. By the 15th day of storage, green matures tomatoes showed firmness of 0.88 $kg/cm^2$ in samples treated with 1.5% $CaCl_2$ and 0.1% $GA_3$. In contrast, on the same day, control samples showed 0.58 $kg/cm^2$ of firmness, which is lower than those of any other treatment. On the 20th day of storage, the highest (0.70kg/$cm^2$) level of firmness was identified in green matured samples treated with 0.1% $GA_3$; on the same day, the control samples showed 0.42 $kg/cm^2$ firmness.

In the case of pink stage tomatoes, highly significant ($p < 0.001$) difference in firmness was seen among the treatments at the initial and 15th days of storage; however, treatments in Days 10 and 20 showed significant ($p < 0.05$) difference. The highest firmness values in Days 10, 15, and 20 were measured as 0.71 $kg/cm^2$, 0.68 $kg/cm^2$, and 0.56 $kg/cm^2$, respectively, in 1.5% $CaCl_2$ treatment. Among the same days, the control samples reported the lowest values at 0.49 $kg/cm^2$, 0.31 $kg/cm^2$, and 0.24 kg/$cm^2$, respectively.

The loss of firmness in fruits is attributed to structural changes in the principal cell wall components (cellulose, hemicelluloses, and pectin). $GA_3$ (Kappel and MacDonald 2002) and $CaCl_2$ (Magee *et al.* 2003) facilitate cell wall integrity and membrane permeability by protecting the cell wall components from degradation. According to Li *et al.* (2012), the addition of calcium improves the rigidity of cell walls and obstructs the activity of enzymes such as polygalacturonase (PG) from reaching their active sites. This process retards tissue softening and ultimately delays the ripening process. Calcium application maintains cell turgor, membrane integrity, and tissue firmness as it also delays membrane lipid catabolism in horticultural crops (Manganaris *et al.* 2007). Similarly, $GA_3$ inhibits the enzymes involved in the ripening process or fruit-softening, and this leads to greater firmness maintenance during the storage of soft fruits (Jawandha *et al.* 2009). The present results were in line with the findings of Mansourbahmani *et al.* (2017), who reported that $CaCl_2$ controlled the ripening by reducing PG activity.

### Effects of $CaCl_2$ and $GA_3$ Dipping on Weight Loss

The result of ANOVA showed statistically non-significant differences in weight loss between postharvest treatments ($CaCl_2$, $GA_3$, and control) at the initial, 5$^{th}$, 10$^{th}$, and 15$^{th}$ day of storage of green matured tomato; in contrast, a highly significant ($p < 0.001$) difference was reported in all the treatments on the 10$^{th}$ day. As indicated in Table 2, the weight loss of tomato fruits increased progressively as the storage duration increases. Weight loss on the 15$^{th}$ day of storage was the highest (6.06%) in control samples and the lowest in tomatoes treated with 0.125% $GA_3$ (3.59%) in the green matured stage. Even though there is no statistical significance among the treatments on the 20$^{th}$ day of storage, the highest weight loss (6.71%) was reported in control samples; in contrast, the lowest (4.36%) weight loss was identified in 0.125% $GA_3$ treated samples.

In the case of pink stage tomatoes, ANOVA of weight loss exhibited a highly significant ($p < 0.001$) difference among the treatments in the control and the 10$^{th}$ and 20$^{th}$ day of storage. In contrast, the 5$^{th}$ and 15$^{th}$ days of storage showed no significant difference among the treatments in weight loss. The highest and lowest weight loss values on the 10$^{th}$ day of storage of pink tomatoes were 5.87% and 3.95% in the control and 1% $CaCl_2$ treated samples, respectively. On the 20$^{th}$ day of storage, the highest and lowest weight loss values were 10.90% and 6.35% in the control and 1.5% $CaCl_2$ treated pink stage tomato samples, respectively.

Green stage tomatoes treated with 0.125% $GA_3$ and 1.5% $CaCl_2$ were better in maintaining weight, but tomatoes treated with 1% $CaCl_2$, 0.075% $GA_3$, and the control had significantly higher weight loss. Similarly, in pink stage tomatoes, weight loss was observed higher compared to that of green stage tomatoes; nevertheless, tomatoes in the pink stage treated with 1.5% $CaCl_2$ had the lowest weight loss during the storage period.

Weight loss of fresh tomatoes was primarily attributed to respiration and transpiration. Generally, the weight loss of tomatoes increases progressively during storage. $CaCl_2$ reported a significant reduction in physiological weight loss right after the second day of storage (Bhattarai and Gautam 2006). The significantly lower weight loss recorded by $CaCl_2$ treated fruits could be attributed to the network formation of calcium with the pectin in the fruit cell wall to restrict moisture loss (Genanew 2013).

Similarly, Özkaya *et al.* (2006) postulated that the reduction in weight loss among the fruits treated with $GA_3$ was due to its anti-senescent action. According to Sharma *et al.* (2018), $GA_3$ treatment leads to a reduction in tissue permeability and water loss. Among the treatments, $GA_3$ (0.1%), $CaCl_2$ (1%), and $CaCl_2$ (1.5%) were found more effective in maintaining the fruit weight; the same trend was also reported by Pila *et al.* (2010) and Senjaliya *et al.* (2015) in tomato storage studies.

### Effects of $CaCl_2$ and $GA_3$ Dipping on TSS

ANOVA showed no statistically significant difference between postharvest treatments ($GA_3$, $CaCl_2$, and control) and TSS in the initial day of green mature tomatoes, but highly significant ($p < 0.001$) differences were observed in the 5$^{th}$, 10$^{th}$, and 15$^{th}$ day of storage (Table 2). Similarly, a significant ($p < 0.05$) difference was observed in the 20$^{th}$ day of storage between the treated and control samples in the green matured stage.

In the case of green matured tomatoes, the highest and lowest TSS values of 5.0 and 4.56$^0$Brix were observed in the control and 0.125% $GA_3$ treated samples, respectively, on the 5$^{th}$ day of storage. Likewise, the highest TSS (5.7$^0$Brix) was found in the control samples and the lowest was identified in the samples treated with 1.5% $CaCl_2$ (5.01$^0$Brix) on the 10$^{th}$ day of storage. By the end of the storage study (20$^{th}$ day), control samples had the maximum TSS (6.43$^0$Brix) value, whereas the least was recorded (6.16$^0$Brix) in green mature tomatoes treated with 1.5% $CaCl_2$.

In the case of the pink stage, ANOVA of TSS showed a statistically insignificant difference in the initial, 5$^{th}$, 10$^{th}$, and 20$^{th}$ days of storage among all the treatments, although there was a highly significant ($p < 0.001$) difference between treatments in Day 15. TSS was found maximum (6.66$^0$Brix) in the control; in contrast, samples treated with $CaCl_2$ (1.5%) showed the lowest (6.63$^0$Brix) for samples stored for 15 d.

The TSS of tomato usually increases as maturity and ripening proceeds during the storage of fruits. This increase was attributed to the breakdown of starch to sugars and hydrolysis of cell wall polysaccharides during the ripening of climacteric fruits (Youssef *et al.* 2012). According to Getinet *et al.* (2008), tomatoes harvested at the matured green stage had the lowest TSS value, while fruits harvested at the light red stage had

**Table 2**. Effect of $CaCl_2$ and $GA_3$ dipping on weight loss (%) and total soluble solid (ºbrix) of green matured and pink stage tomatoes stored for 20 d.

| Treatment | Level (%) | Weight loss (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Storage (d) | | | | | Pink stage Storage (d) | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| **$CaCl_2$** | 1 | ND | 1.27 | 2.13 | $3.94^{bc}$ | 6.01 | ND | 2.27 | $3.95^{c}$ | 6.32 | **$8.54^{ab}$** |
| | 1.5 | ND | 1.27 | $2.16^{b}$ | $3.93^{bc}$ | 4.37 | ND | 2.28 | $4.20^{c}$ | 6.29 | **$6.35^{c}$** |
| | 2 | ND | 1.27 | 2.12 | $4.07^{bc}$ | 5.21 | ND | 2.28 | $4.49^{bc}$ | 6.28 | **$6.63^{bc}$** |
| **$GA_3$** | 0.125 | ND | 1.27 | 2.13 | $3.59^{c}$ | 4.36 | ND | 2.27 | $5.52^{ab}$ | 6.93 | **$7.70^{abc}$** |
| | 0.1 | ND | 1.28 | 2.22 | $4.08^{bc}$ | 4.79 | ND | 2.50 | $5.65^{a}$ | 7.13 | **$8.99^{ab}$** |
| | 0.075 | ND | 1.30 | 2.18 | $5.49^{ab}$ | 5.56 | ND | 2.29 | $5.44^{ab}$ | 6.72 | **$7.44^{abc}$** |
| **Control** | 0 | ND | 1.31 | 2.17 | $6.06^{a}$ | 6.71 | ND | 2.29 | $5.87^{a}$ | 8.28 | **$10.90^{a}$** |
| **LSD (5%)** | | - | 0.04 | 0.14 | 1.87 | 2.03 | - | ND | 1.12 | 2.52 | **3.58** |
| **CV (%)** | | - | 2.16 | 3.45 | 3.20 | 4.30 | - | 5.45 | 1.01 | 7.76 | **5.387** |
| **Significance level** | | - | ns | ns | *** | ns | - | ns | *** | ns | *** |

| Treatment | Level (%) | Total soluble solid (ºbrix) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Storage (d) | | | | | Pink stage Storage (d) | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| **$CaCl_2$** | 1 | 3.03 | 4.73cd | $5.26^{b}$ | $6.16^{a}$ | $6.23^{ab}$ | 6.29 | $6.50^{a}$ | 6.53 | $6.83^{a}$ | **7.46** |
| | 1.5 | 3.04 | $4.77^{bc}$ | $5.01^{b}$ | $5.83^{b}$ | $6.16^{b}$ | 6.29 | $6.33^{a}$ | 6.53 | $6.63^{b}$ | **7.70** |
| | 2 | 3.01 | $4.90^{ab}$ | $5.16^{b}$ | $6.06^{ab}$ | $6.33^{ab}$ | 6.30 | $6.53^{a}$ | 6.56 | $6.83^{a}$ | **7.80** |
| **GA3** | 0.125 | 3.05 | $4.56^{d}$ | $5.23^{b}$ | $5.96^{ab}$ | $6.13^{b}$ | 6.30 | $6.43^{a}$ | 6.60 | $6.767^{a}$ | **7.85** |
| | 0.1 | 3.03 | $4.66c^{d}$ | $5.13^{b}$ | $5.96^{ab}$ | $6.23^{ab}$ | 6.32 | $6.60^{a}$ | 6.63 | $6.767^{a}$ | **8.33** |
| | 0.075 | 3.03 | $4.66c^{d}$ | $5.03^{b}$ | $5.96^{ab}$ | $6.23^{ab}$ | 6.31 | $6.46^{a}$ | 6.63 | $6.80^{a}$ | **7.70** |
| **Control** | 0 | 3.19 | $5.00^{a}$ | $5.75^{a}$ | $6.23^{a}$ | $6.43^{a}$ | 6.33 | $6.60^{a}$ | 6.66 | $6.867^{a}$ | **7.93** |
| **LSD (5%)** | | 0.23 | 0.19 | 0.31 | 0.28 | 0.24 | 0.03 | 0.26 | 0.18 | 0.11 | **0.67** |
| **CV (%)** | | $4.98^{ns}$ | 0.78 | 1.56 | 0.68 | 1.20 | 0.27 | 2.09 | 1.541 | 0.78 *** | **3.39** |
| **Significance level** | | **ns** | *** | *** | *** | ** | **ns** | **ns** | **ns** | *** | **ns** |

Means followed by the same letters(s) within the same column are not significantly different at 5% level of significance; ***highly significant, **significant, ns – non-significant, ND – not detected

the highest TSS. In this study, the TSS values of tomato fruit treated with $GA_3$ and $CaCl_2$ were lower than those of the control samples. The lower TSS values in $CaCl_2$ treated tomato fruits in this study were probably due to a reduction in respiration, metabolic activity, and ripening process. This result was in line with the report of Chéour *et al.* (1991), who reported that concentration of free sugars progressively increased with storage; this increase was markedly delayed by $CaCl_2$ treatment in soft fruits. Mohamed *et al.* (2007) also reported a significant reduction in TSS value in $GA_3$ treated banana fruits. The reduction in TSS in the fruits treated with $GA_3$ was attributed to the slower respiration and metabolic activity, which delays the ripening process (Pila *et al.* 2010).

### Effects of $CaCl_2$ and $GA_3$ Dipping on TA

All postharvest treatments showed statistically non-significant differences in TA on the initial and 5th day of storage in green mature tomato. On the other hand, a highly significant ($p < 0.001$) difference was observed in green matured tomatoes stored for 10, 15, and 20 d of different postharvest treatments. As shown in Table 3, the TA of treated tomato fruits decreased progressively during storage. TA was observed highest in green matured tomatoes treated with 1.5% $CaCl_2$ (0.24%); in contrast, the lowest TA was observed in the control (0.20%) on the 10th day of storage. On the 15th day of storage, 1.5% $CaCl_2$ treated green matured tomatoes showed a higher TA (0.22%) while the lower (0.18%) TA was determined in 1% $CaCl_2$ and control. Similar trends were also observed on the 20th day for green mature tomatoes.

**Table 3.** Effect of $CaCl_2$ and $GA_3$ dipping on titratable acidity (%) and β-carotene (mg/l) change of green matured and pink stage tomatoes stored for 20 d.

| Treatment | Level (%) | Titratable acidity (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Storage (d) | | | | | Pink stage Storage (d) | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| **$CaCl_2$** | 1 | 0.26 | 0.24 | 0.21$^{b}$ | 0.18$^{c}$ | 0.17$^{b}$ | 0.31 | 0.28$^{bc}$ | 0.23$^{d}$ | 0.19$^{c}$ | **0.15$^{c}$** |
| | 1.5 | 0.27 | 0.23 | 0.24$^{a}$ | 0.22$^{a}$ | 0.19$^{a}$ | 0.30 | 0.31$^{a}$ | 0.28$^{a}$ | 0.23$^{a}$ | **0.18$^{a}$** |
| | 2 | 0.24 | 0.23 | 0.21$^{b}$ | 0.20$^{b}$ | 0.17$^{b}$ | 0.30 | 0.29$^{abc}$ | 0.26$^{b}$ | 0.20$^{cb}$ | **0.17$^{ab}$** |
| **GA3** | 0.125 | 0.25 | 0.24 | 0.22$^{ab}$ | 0.20$^{b}$ | 0.17$^{b}$ | 0.30 | 0.30$^{ab}$ | 0.25$^{bcd}$ | 0.20$^{cb}$ | **0.16$^{bc}$** |
| | 0.1 | 0.25 | 0.24 | 0.21$^{b}$ | 0.18$^{c}$ | 0.16$^{c}$ | 0.29 | 0.30$^{ab}$ | 0.26$^{bc}$ | 0.21$^{b}$ | **0.18$^{ab}$** |
| | 0.075 | 0.25 | 0.24 | 0.22$^{ab}$ | 0.19$^{c}$ | 0.16$^{c}$ | 0.31 | 0.29$^{abc}$ | 0.25$^{bcd}$ | 0.19$^{c}$ | **0.15$^{ab}$** |
| **Control** | 0 | 0.26 | 0.25 | 0.20$^{b}$ | 0.18 | 0.16$^{d}$ | 0.29 | 0.27$^{c}$ | 0.24$^{cd}$ | 0.18$^{c}$ | **0.17$^{ab}$** |
| **LSD (5%)** | | 0.02 | 0.02 | 0.02 | 0.005 | 0.003 | 0.01 | 0.02 | 0.02 | 0.01 | **0.01** |
| **CV (%)** | | 3.64$^{ns}$ | 5.75$^{ns}$ | 0.21 | 0.19 | 0.002 | 1.24$^{ns}$ | 0.29 | 0.25 | 0.20 | **0.18** |
| **Significance level** | | ns | ns | *** | *** | *** | ns | *** | *** | *** | *** |

| Treatment | Level (%) | β-carotene (mg/l) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Storage (d) | | | | | Pink stage Storage (d) | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| **$CaCl_2$** | 1 | 0.010 | 0.21$^{c}$ | 0.45$^{d}$ | 0.65$^{a}$ | 0.73$^{b}$ | 0.97 | 1.07$^{b}$ | 1.14$^{c}$ | 1.24 | **1.40$^{bc}$** |
| | 1.5 | 0.010 | 0.22$^{bc}$ | 0.38$^{e}$ | 0.62$^{b}$ | 0.69$^{c}$ | 0.96 | 1.01$^{d}$ | 1.10$^{d}$ | 1.24 | **1.39$^{cd}$** |
| | 2 | 0.010 | 0.22$^{ab}$ | 0.47$^{b}$ | 0.66$^{a}$ | 0.75$^{a}$ | 0.97 | 1.07$^{b}$ | 1.16$^{b}$ | 1.29 | **1.41$^{ab}$** |
| **GA3** | 0.125 | 0.010 | 0.22$^{bc}$ | 0.47$^{bc}$ | 0.65$^{a}$ | 0.68$^{c}$ | 0.99 | 1.03$^{c}$ | 1.15$^{b}$ | 1.27 | **1.39$^{d}$** |
| | 0.1 | 0.013 | 0.23$^{a}$ | 0.44$^{d}$ | 0.63$^{b}$ | 0.70$^{c}$ | 0.97 | 1.02$^{cd}$ | 1.10$^{d}$ | 1.28 | **1.40$^{bcd}$** |
| | 0.075 | 0.016 | 0.22$^{ab}$ | 0.45$^{cd}$ | 0.67$^{a}$ | 0.69$^{c}$ | 0.98 | 1.04$^{c}$ | 1.10$^{d}$ | 1.28 | **1.41$^{ab}$** |
| **Control** | 0 | 0.013 | 0.22$^{ab}$ | 0.50$^{a}$ | 0.67$^{a}$ | 0.75$^{a}$ | 0.98 | 1.10$^{a}$ | 1.17$^{a}$ | 1.29 | **1.42$^{a}$** |
| **LSD (5%)** | | 0.007 | 0.00 | 0.01 | 0.02 | 0.02 | 0.04 | 0.02 | 0.0085 | 0.25 | **0.01** |
| **CV (%)** | | 8 | 0.06 | 0.02 | 0.04 | 0.71 | 2.35$^{s}$ | 1.06 | 1.13 | 1.63$^{ns}$ | **1.20** |
| **Significance level** | | **ns** | ** | *** | *** | *** | **ns** | *** | *** | **ns** | *** |

Means followed by the same letters(s) within the same column are not significantly different at 5% level of significance; ***highly significant, **significant, ns – non-significant, ND – not detected

In the case of pink stage tomatoes, ANOVA analysis showed a statistically insignificant difference in TA on the initial storage day. However, in the 5$^{th}$, 10$^{th}$, 15$^{th}$, and 20$^{th}$ days of storage, TA showed a highly significant ($p < 0.001$) difference among the different treatments. The lowest amount of TA on Day 5 was observed from the control (0.27) while the highest (0.31%) TA was recorded in pink stage tomatoes treated with 1.5% $CaCl_2$. Higher TA on the 10$^{th}$ day was observed in pink stage tomatoes dipped in 1.5% $CaCl_2$ (0.28%), and the lower TA (0.23%) was from those with 1% $CaCl_2$. The highest and lowest TA in the pink stage at Day 15 of storage was 0.23%, and 0.18% was observed in the control and 1.5% $CaCl_2$ treated pink stage samples, respectively. However, the highest (0.18%) TA was identified in 1.5% $CaCl_2$ and 0.1% $GA_3$ treated tomatoes, while the lowest TA was found in the control tomatoes on the 20$^{th}$ day of storage.

The retention of higher TA in $CaCl_2$ and $GA_3$ treated fruits might be due to the reduction in metabolic changes from organic acid to carbon dioxide and water. As previously stated, both treatments ($CaCl_2$ and $GA_3$) delay the ripening process, which leads to the maintenance of TA in storage durations of the treated tomatoes. These results are in agreement with the study of Oz and Ulukanli (2014), who reported higher retention of TA in the $CaCl_2$ treated fruits during storage.

**Effects of $CaCl_2$ and $GA_3$ Dipping on β-carotene**

The change in β-carotene concentrations in green mature tomatoes was insignificantly affected on the initial day in all post-harvest treatments. However, a highly significant ($p < 0.001$) difference was observed in green mature tomato fruits stored for 5, 10, 15, and 20 d among all treatments and control. As presented in Table 3, the β-carotene content of green matured tomatoes increased progressively during storage. The highest β-carotene content was recorded in pink stage tomatoes treated with 2% $CaCl_2$ (0.75 mg/l) while the lowest was recorded in tomatoes treated with 0.125% $GA_3$ (0.68 mg/l). Also, the highest (0.75 mg/l) β-carotene content from untreated tomatoes was identified on the 20$^{th}$ day of storage, which is similar to the 2% $CaCl_2$ treatment.

β-carotene in pink stage tomatoes recorded statistically insignificant difference on the initial and 15$^{th}$ day in all post-harvest treatments while those on the 5$^{th}$, 10$^{th}$, and 20$^{th}$ day of storage showed a highly significant difference ($p < 0.001$) in all post-harvest treatments. The lowest (1.02 mg/l) β-carotene content was recorded in pink stage tomatoes treated with 0.1% $GA_3$ stored for 5 d while the highest (1.1mg/l) was observed in the control samples. As presented in Table 3, the highest β-carotene (1.17 mg/l) on the 10$^{th}$ day was identified in the control and the lowest (1.1gm/l) was obtained in tomatoes treated with 1.5% $CaCl_2$. The highest and lowest β-carotene in pink stage tomatoes on the 20$^{th}$ day was 1.42 mg/l and 1.39 mg/l observed in the control and 0.125% $GA_3$ treated samples, respectively.

The increase in β-carotene can be attributed to the unmasking of the carotenoids following chlorophyll degradation during the ripening of tomatoes (Su *et al.* 2015). Msogoya *et al.* (2014) reported that longer storage durations resulted in a higher loss of β-carotene content, accompanied by the progression of senescence. Application of $GA_3$ and $CaCl_2$ delayed the degradation of chlorophylls and the development of carotenoids (Williamson and Benkeblia 2015).

**Effects of $CaCl_2$ and $GA_3$ Dipping on Lycopene**

The lycopene content was not statistically significant between postharvest treatments on the initial, 5$^{th}$, and 10$^{th}$ days of storage among the treatments and control samples. However, on the 15$^{th}$ and 20$^{th}$ day, a highly significant ($p < 0.001$) difference was seen among the treated green matured tomatoes (Table 4). Treated fruits showed a lower and slower accumulation of lycopene in green matured tomatoes stored for 15 and 20 d. The lycopene content generally increased with the advancement in maturity during storage. The highest (0.12 mg/l) lycopene content on the 15$^{th}$ day of storage was observed in the control and 0.075% $GA_3$ treated samples. However, the lowest (0.11 mg/l) lycopene content was identified tomatoes treated with 1%, 1.5%, and 2% $CaCl_2$ plus 0.1% and 0.125% $GA_3$. Similarly, on the 20$^{th}$ day of storage, the highest lycopene content (0.27 mg/l) was observed in the control and 0.125% $GA_3$ treated samples; however, the lowest (0.24 ml/g) was determined in 0.1% $GA_3$ treated green matured tomatoes.

The result of ANOVA showed a statistically non-significant difference on the initial and 5$^{th}$ day for pink stage tomato samples, but there is a highly significant ($p < 0.001$) difference among treatments on the 10$^{th}$, 15$^{th}$, and 20$^{th}$ day of storage. The highest lycopene (0.766 mg/l) at Day 10 was determined in the control while the lowest (0.74 mg/l) was identified in 1% $CaCl_2$ treated pink stage tomatoes. Untreated and tomatoes treated with 0.075% $GA_3$ showed the highest lycopene content (0.83 mg/l), whereas the lowest (0.81mg/l) was reported on the 15$^{th}$ day of storage of 1% and 1.5% $CaCl_2$ treated samples. On the 20$^{th}$ day, the highest (0.91 mg/l) and lowest (0.86 mg/l) lycopene content was recorded in the control and $GA_3$ treated fruits, respectively. Application of $GA_3$ and $CaCl_2$ delayed the degradation of chlorophylls and the development of carotenoids. Similar findings were reported by Khader (1991) and Sudha *et al.* ( 2007).

**Effects of $CaCl_2$ and $GA_3$ Dipping on pH**

ANOVA indicated no significant difference between post-harvest treatments and pH on the initial, 5$^{th}$, and 20$^{th}$ days of storage. However, a highly significant ($p < 0.001$) effect was observed in green matured tomatoes among all the treatments after 10 and 15 d of storage (Table 4). The pH value of tomato generally increased as the fruit ripens due to the conversion of acids into sugars. The highest (3.59) and lowest (3.49) pH value of green matured tomato fruits on the 10$^{th}$ day was observed from 1.5% $CaCl_2$ treated and the control samples, respectively. Similarly, on the 15$^{th}$ day of storage, the highest pH of tomato fruit (4.69) was from the control and the lowest (4.56) was from the 1.5% $CaCl_2$ treated samples.

In the case of pink stage tomato, ANOVA showed no statistically significant difference in pH on the initial, 5$^{th}$, and 15$^{th}$ day of storage among all postharvest treatments, but there was a highly significant ($p < 0.001$) difference between treatments on the 10$^{th}$ day and significant ($p < 0.05$) difference on the 20$^{th}$ day of stored pink stage tomatoes. The highest pH value (4.39) on Day 10 was observed from the control and the lowest (4.33) was identified in samples treated with 2% $CaCl_2$. The highest pH value (5.51) was recorded in the control; in contrast, the lowest pH value (5.42) was recorded on the 20$^{th}$ day of storage for 1.5% $CaCl_2$ and 0.125% $GA_3$ treated samples.

The fluctuations in pH might be due to the variations in TA. A decline in acidity was attributed to increased

**Table 4**. Effect of $CaCl_2$ and $GA_3$ dipping on lycopene and pH of green matured and pink stage tomatoes storage for 20 d.

| Treatment | Level (%) | Lycopene (mg/l) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Storage (d) | | | | | Pink stage Storage (d) | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| **$CaCl_2$** | 1 | 0.05 | 0.067 | 0.08 | $0.11^{b}$ | $0.25^{b}$ | 0.37 | 0.52 | $0.7466^{b}$ | $0.82^{a}$ | **$0.88^{cb}$** |
| | 1.5 | 0.05 | 0.062 | 0.08 | $0.11^{b}$ | $0.25^{b}$ | 0.38 | 0.52 | $0.75^{ab}$ | $0.81^{b}$ | **$0.86^{e}$** |
| | 2 | 0.05 | 0.062 | 0.08 | $0.11^{b}$ | $0.27^{a}$ | 0.38 | 0.52 | $0.75^{ab}$ | $0.84^{a}$ | **$0.89^{b}$** |
| **$GA_3$** | 0.125 | 0.05 | 0.063 | 0.08 | $0.11^{b}$ | $0.27^{a}$ | 0.38 | 0.52 | $0.75^{b}$ | $0.83^{a}$ | **$0.86^{e}$** |
| | 0.1 | 0.05 | 0.062 | 0.08 | $0.11^{b}$ | $0.24^{c}$ | 0.38 | 0.52 | $0.75^{b}$ | $0.82^{ab}$ | **$0.87^{cd}$** |
| | 0.075 | 0.05 | 0.065 | 0.08 | $0.116^{a}$ | $0.25^{a}$ | 0.37 | 0.52 | $0.76^{a}$ | $0.82^{ab}$ | **$0.88^{bcd}$** |
| **Control** | 0 | 0.05 | 0.063 | 0.08 | $0.120^{a}$ | $0.27^{a}$ | 0.38 | 0.52 | $0.76^{a}$ | $0.83^{a}$ | **$0.91^{a}$** |
| **LSD (5%)** | | 0.0008 | 0.0004 | - | 0.0039 | 0.006 | 0.008 | 0.001 | 0.0162 | 0.029 | **0.015** |
| **CV (%)** | | 3.2 | 0.38 | 1.52 | 0.80 | 2.60 | 1.34 | 0.796 | 0.453 | 0.522 | **0.444** |
| **Significance level** | | ns | ns | ns | *** | *** | ns | ns | *** | *** | *** |

| Treatment | Level (%) | pH | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green stage Days of storage | | | | | Pink stage Days of storage | | | | |
| | | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | **20** |
| **$CaCl_2$** | 1 | 3.36 | 3.46 | $3.54^{bc}$ | $4.62^{abc}$ | 4.71 | 3.28 | 3.36 | $4.37^{a}$ | 4.52 | **$5.44^{b}$** |
| | 1.5 | 3.39 | 3.49 | $3.49^{d}$ | $4.56^{c}$ | 4.63 | 3.27 | 3.35 | $4.35^{ab}$ | 4.47 | **$5.42^{b}$** |
| | 2 | 3.38 | 3.48 | $3.57^{ab}$ | $4.58^{bc}$ | 4.68 | 3.29 | 3.32 | $4.33^{b}$ | 4.53 | **$5.46^{ab}$** |
| **$GA_3$** | 0.125 | 3.39 | 3.44 | $3.52^{dc}$ | $4.66^{ab}$ | 4.65 | 3.28 | 3.36 | $4.37^{a}$ | 4.56 | **$5.44^{b}$** |
| | 0.1 | 3.38 | 3.48 | $3.54^{bc}$ | $4.62^{abc}$ | 4.68 | 3.28 | 3.38 | $4.38^{a}$ | 4.53 | **$5.42^{b}$** |
| | 0.075 | 3.40 | 3.46 | $3.56^{abc}$ | $4.68^{ab}$ | 4.72 | 3.26 | 3.33 | $4.39^{a}$ | 4.52 | **$5.50^{a}$** |
| **Control** | 0 | 3.37 | 3.44 | $3.59^{a}$ | $4.69^{a}$ | 4.76 | 3.28 | 3.30 | $4.39^{a}$ | 4.58 | **$5.51^{a}$** |
| **LSD (5%)** | | 0.05 | 0.08 | 0.04 | 0.09 | 0.12 | 0.07 | 0.11 | 0.04 | 0.09 | **0.07** |
| **CV (%)** | | 0.85 | 1.35 | 0.02 | 0.08 | 1.40 | 0.96 | 1.43 | 0.59 | 1.01 | **1.00** |
| **Significance level** | | **ns** | **ns** | *** | *** | **ns** | **ns** | **ns** | *** | **ns** | ** |

Means followed by the same letters(s) within the same column are not significantly different at 5% level of significance; ***highly significant, **significant, ns – non-significant, ND – not detected

activity of citric acid glyoxylase during ripening (Rathore *et al.* 2007). Pila *et al.* (2010) reported that treatment of $CaCl_2$ at 1 and 1.5% concentrations were significantly good in maintaining low pH, as compared to untreated fruits. The findings of the present study were consistent with the findings of Chéour *et al.* (1991), who reported that the postharvest application of $CaCl_2$ in fruits maintained the lower pH of fruits during the storage.

### Effects of $CaCl_2$ and $GA_3$ Dipping on Decay Percentage

ANOVA showed high significant ($p < 0.001$) decay among the control and on the 10th, 15th, and 20th days of storage in green matured tomatoes. Until the 10th day of storage, all $CaCl_2$-treated samples reported no decay; this trend was also seen on the 15th day of 1 and 1.5% $CaCl_2$ treated green matured tomatoes. In the case of those on the 20th day of storage, decay was reported in 25% of the 1.5% $CaCl_2$ treated samples. In the case of $GA_3$ treatments, until the 5th day, no decay was reported. However, by the 10th day, decay was reported in 11.66% of 0.125% treated green mature tomatoes. The maximum decay (35%) was observed on the 20th day of storage in 0.075% $GA_3$ treated samples. By the 20th day, 60% of the control fruits were reportedly in decay (Appendix Figure I). In comparison, the control tomato is better in maintaining shelf life.

In the case of the pink stage, ANOVA showed a highly significant ($p < 0.001$) difference in tomato stored for 10, 15, and 20 days among all the treatments. The highest and lowest decay percentages on the 10th day was 20%

(control) and 5% (1.5% $CaCl_2$ and 0.1% $GA_3$); by the 20th day, the values were 85% (control) and 20% (1.5% $CaCl_2$ and 0.1% $GA_3$).

$CaCl_2$ treatments resulted in the reduction of decay percentage. Chardonnet *et al.* (2003) reported that changes in firmness amid the degradation of cell walls lead to a consequent reduction in fruit quality. The loss of firmness due to cell wall carbohydrate metabolism during storage has been associated with increased susceptibility to infection by fungal pathogens. Bhattarai and Gautam (2006) stated that $CaCl_2$ (1.0%) is the most effective in enhancing the storage life of tomato fruit. Gol and Rao (2011) reported that postharvest coatings of fruits in $GA_3$ delayed the conversion of starch into sugars and reduced peroxidase activity and ethylene production. The results of Chéour *et al.* (1991) reported that the application of $CaCl_2$ prolonged the storage life of berry fruits. Pila *et al.* (2010) reported that $CaCl_2$ application helps in the maintenance of membrane integrity, tissue firmness, and cell turgor, as well as in the delay of membrane lipid catabolism and extension of storage life.

## CORRELATION ANALYSIS BETWEEN STUDIED PARAMETERS

The present study showed that, in green tomato, the color change is positively correlated with firmness, weight loss, TSS, β-carotene, lycopene, pH, and decay percentage. Firmness was shown to be positively correlated with weight loss, TSS, β-carotene, lycopene, pH, and decay percentage. In contrast, TA was negatively correlated with firmness. Weight loss is positively correlated with TSS, β-carotene, lycopene, pH, and decay percentage. However, the TA was negatively correlated (–0.35) with weight loss. TSS is positively correlated with β-carotene, lycopene, pH, and decay percentage; on the other hand, TA (–0.44) is negatively correlated. β-carotene concentration is positively correlated with lycopene, pH, and decay percentage. Finally, a positive correlation was observed between pH and decay percentage (Appendix Table I).

Similarly, at the pink stage, the color change is negatively correlated with firmness and TA (–0.24 and –0.04) and positively correlated with weight loss and TSS, β-carotene, lycopene, pH, and decay percentage. Firmness is negatively correlated with weight loss (–0.43) but positively correlated with TSS, β-carotene, lycopene, pH, and decay percentage. In the case of weight loss, it is positively correlated with TSS, β-carotene, lycopene, pH, and decay percentage. In contrast, TA was negatively correlated (–0.29) with weight loss. TSS is positively correlated with β-carotene, lycopene, pH, and decay percentage. β-carotene was positively correlated with lycopene, pH, and decay percentage. A positive correlation was observed between pH and decay percentage.

## CONCLUSION

The overall quality of the $CaCl_2$ and $GA_3$ treated tomatoes was better than the control since these treatments delayed the ripening process more effectively and with minimum quality loss. Finally, the treated tomatoes had a shelf life of up 20 days for pink and green maturity stages; with personal interest, we observed that the last tomato reportedly decayed after 32 d in the green matured stage. Based on the results of the present study, 0.1 and 0.125% $GA_3$ plus 1 and 1.5% $CaCl_2$ treatments showed optimum shelf life and maintained quality characteristics compared to the control. Thus, it may be implied that tomatoes stored at green mature stage treated with 0.125% $GA_3$ may have better quality and shelf life, and pink tomatoes treated with 1.5% $CaCl_2$ may be more effective in reducing deterioration percentage.

## ACKNOWLEDGMENTS

All the authors are grateful to the Deans of the College of Agriculture and Environmental Sciences and of the Faculty of Chemical and Food Engineering at Bahir Dar University for providing the facilities for the successful completion of this research.

## NOTE ON APPENDICES

The complete appendices section of the study is accessible at http://philjournsci.dost.gov.ph

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# APPENDICES

## Details on the Data Collection Methods Used in This Study

***Color change.*** The change in fruit color was analyzed according to the method described by Batu (2004) and Khairia *et al.* (2015). Skin color was measured using a portable colorimeter (model: CM-600d spectrophotometer, Konica Minolta, Japan) calibrated with a standard white plate (L* = 96; a* = 0.14*; b* = 1.63). Color measurement was performed on the surface of the tomatoes at three points in the equatorial region of fruits. Then, redness compared to yellowness (a*/b*) was determined.

***Fruit firmness.*** Fruit firmness was measured using the method of Kitinoja and Hussein (2005). Texture analyzer (model: TA-XT plus texture analyzer, serial no. 40689, Stable Micro System, UK) with flat head stainless-steel cylindrical probe (batch no. 13046) of 2 mm diameter was used for the measurement of tomato fruit firmness. A distance of 5 mm, load cell of 5 kg, and pretest, test, post-test speeds of 10, 2, and 10 mm/s were used, respectively. The firmness was observed in three different locations on fruit (soft, strong, and medium). The maximum force was recorded at each point used and the average was recorded as firmness ($kg/cm^2$).

***Weight loss.*** The initial and final weights of fruit samples in each storage duration intervals were weighed and the differences in weight were expressed as a percentage of weight loss from the initial weight of the samples (Pila *et al.* 2010).

***TSS value.*** The TSS content of the tomato fruit juice was determined by using a handheld refractometer (RX-5000i- plus, Japan). The prepared juice sample was thoroughly mixed and few drops were placed on the prism of the refractometer, direct reading was taken by reading in the mirror scale, and the values were reported as degree Brix (Gerefa *et al.* 2015).

***TA value.*** Twenty milliliters (20 ml) of the prepared juice sample were taken into a 100-ml conical flask and 10 ml of water was added to make the fruit juice color lighter. To determine the total titratable acidity of the pulp, the samples were neutralized with 0.1 N NaOH until it turns to light pink color. Phenolphthalein was used as the indicator to determine the endpoint, and the TA results were expressed in percentage of citric acid (Gerefa *et al.* 2015). The percentage of TA was calculated using the following equation:

$$Titratable\ acidity\ \% = \frac{ml\ of\ NaoH \times 0.0064}{ml\ of\ juice} \times 100 \qquad (1)$$

***Lycopene and β-carotene content.*** Mashed, homogenized 1 g of tomato sample was taken into a 50-ml beaker. Pigments in the sample were extracted using acetone and hexane solvent by the ratio of 3:4. A separate pigment layer was taken using a quartz cuvette and absorbance was measured at 663, 645, 505, and 453 nm using a UV-visible spectrophotometer (SP-VIS100, Italy) (Nagata and Yamashita 1992). Equations 2 and 3 were used to determine lycopene and β-carotene concentrations in the tomato samples:

$$\text{Lycopene (mg/ 100 ml)} = -0.0458A_{663} + 0.204A_{645} + 0.372A_{505} - 0.0806A_{453} \qquad (2)$$

$$\beta\text{-carotene (mg/ 100ml)} = 0.216A_{663} - 1.22A_{645} - 0.304A_{505} + 0.452A_{453} \qquad (3)$$

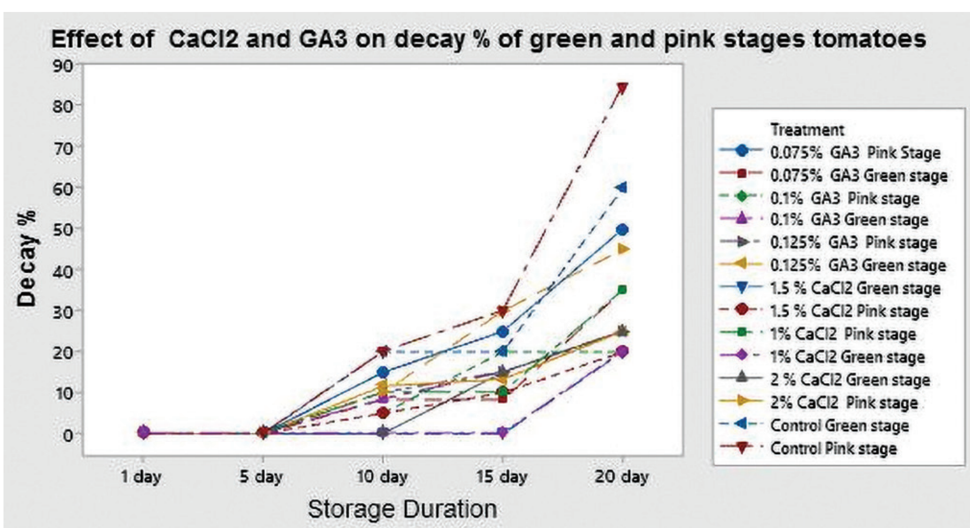
***Determination of pH.*** The pH values of tomato samples were determined using the method described by Gerefa *et al.* (2015). The tomato fruit samples were converted to a pulp using a kitchen blender (Model: Ovente JE1034P Electric Juicer, China) and filtered through a muslin cloth. Then, the pH was measured by using a calibrated pH meter (model: PHS-25CW, Benchtop pH/mV Meter, China) with neutral (pH 7.0) and acidic (pH 4.01) buffer solutions.

***Decay or rotting.*** The decay or rotting of the stored tomato fruits was determined in each interval through visual observations. The decay percentage of tomato fruits was calculated as the number of decayed fruit by the initial number of fruits used in the study (Pila *et al.* 2010).

**Appendix Table I.** Correlation table of different physicochemical properties in green mature and pink stages of tomatoes.

| Response | Green mature stage | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | CC | FIR | WL | TSS | TA | βCAR CAR | LYCO | pH | DCY |
| CC | 1 | 0.16 | 0.34 | 0.29 | –0.68 | 0.07 | 0.05 | 0.37 | 0.73** |
| FIR | | 1 | 0.34 | 0.40 | –0.34 | 0.45* | 0.62* | 0.21 | 0.48* |
| WL | | | 1 | 0.43* | –0.35 | 0.25 | 0.06 | 0.45* | 0.23 |
| TSS | | | | 1 | –0.44* | 0.35 | 0.23 | 0.11 | 0.45* |
| TA | | | | | 1 | –0.32 | 0.17 | –0.36 | –0.6 |
| B-CAR | | | | | | 1 | 0.45* | 0.32 | 0.44 |
| LYCO | | | | | | | 1 | 0.04 | 0.43* |
| PH | | | | | | | | 1 | 0.43* |
| DCY | | | | | | | | | 1 |
| **Response** | **Pink stage** | | | | | | | | |
| | CC | FIR | WL | TSS | TA | βCAR | LYCO | pH | DCY |
| CC | 1 | –0.24 | 0.19 | 0.11 | –0.04 | 0.03 | 0.26 | 0.5 | 0.1* |
| FIR | | 1 | –0.43* | 0.40 | 0.2 | 0.46 | 0.33 | 0.29 | 0.41* |
| WL | | | 1 | 0.51 * | –0.29 | 0.49* | 0.43* | 0.34 | 0.6** |
| TSS | | | | 1 | 0.49* | 0.4* | 0.50* | 0.48* | 0.62** |
| TA | | | | | 1 | –0.03 | –0.05 | –0.22 | –0.10 |
| B-CAR | | | | | | 1 | 0.77** | 0.074 | 0.80** |
| LYCO | | | | | | | 1 | 0.32 | 0.78** |
| pH | | | | | | | | 1 | 0.37 |
| DCY | | | | | | | | | 1 |

CC – color change, FIR – firmness, WL – weight loss, TSS – total soluble solid, TA – titrable acidity, βCAR – β-carotene, LYCO – lycopene, DCY – decay percentage; *significant, **highly significant




**Appendix Figure I.** Effect of the different concentrations of the $CaCl_2$ and $GA_3$ on decay% of the green and pink stage tomatoes preserved for 20 d.