ISSN 2518–2021 (Print) 2415–4474 (Electronic)

Fundamental and Applied Agriculture

Journal home page: https://www.f2ffoundation.org/faa/index.php/home

Vol. 9(3), pp. 213 – 219: 2024, doi: https://doi.org/10.5455/faa.190035

PLANT NUTRITION | ORIGINAL ARTICLE

Efficacy of Different Concentration of Calcium Chloride on Post-Harvest Quality of Tomato (*Solanum lycopersicum* L.)

Sabnam Subedi[1], Aman Mehta[2] ✉, Alina Thapa[1], Dipak Kattel[1], Shiva Shankar Bhattari[3]

[1] Institute of Agriculture and Animal Science, Tribhuvan University, Mahendra Ratna Multiple Campus, Ilam, Nepal

[2] Faculty of Agriculture, Agriculture and Forestry University, Rampur, Nepal

[3] Institute of Agriculture and Animal Science, Tribhuvan University, Paklihawa Campus, Bhairahawa, Nepal

ARTICLE INFO

Article history

Received: 11 Aug 2024

Accepted: 28 Sep 2024

Published online: 30 Sep 2024

Keywords

Acidity, Juice recovery percentage, Physiological loss, Total soluble solid, Shelf-life

Correspondence

Aman Mehta

✉: mehtaaman048@gmail.com

ABSTRACT

Postharvest loss in tomatoes is significantly high after harvest, due to several factors. The study on the effect of different concentrations of calcium chloride on shelf life and quality of tomato (*Solanum lycopersicum* L.) at the time of storage was done at the Nepal Agriculture Research Council (NARC), Tarahara, Sunsari, during the period from February to March 2023. Tomato (Srijana variety) fruit with stem stalk was harvested at breaker stage and dipped either in distilled water as a control or in different concentrations of calcium chloride ($CaCl_2$) (0.5, 1, 1.5, 2, 2.5, and 3%) for 15 minutes. The fruits were then air-dried and stored at ambient temperatures. The experiment was laid out in a completely randomized design (CRD) with three replications and seven treatments at the ambient temperature of 20±1 °C and an RH of 60±2 %. The shelf life and physicochemical characteristics of tomato fruit were studied at a 2-day interval during storage. The parameters recorded were physiological loss in weight (PLW), juice content (JC), total soluble solids (TSS), acidity (A), and pH in everyday intervals up to 16 days. The data was analyzed using R software, and a significant difference was calculated at a 1% significance level. Among the different treatments used in the laboratory, $CaCl_2$ at 3% concentration was found to be the most effective in reducing the physiological loss in weight (12.65%), highest acidity (0.72%), lowest pH (4.27), lowest TSS (5.13 °Brix), and highest juice recovery (22.64%). It was observed that tomatoes treated with calcium chloride had an extended shelf life and quality for 16 days compared to those left untreated (control).

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the many potential vegetables that are grown on a commercial-to-subsistence basis from the Terai to the Nepalese hills (Rijal et al., 2018). The tomato is a subtropical annual crop that is a member of the solanaceous family (Nuhu & Zarami, 2023). It is the fourth most important vegetable crop, with a total productive area of 22,566 hectares and an average production of 406,434 metric tons, i.e., 18.01 metric tons per hectare, in the fiscal year 2018–19 (MoALD, 2020). Similarly, it spans about 21,747 hectares with an average production scale of 413,761 metric tons, i.e., 19.03 metric tons per hectare, in the fiscal year 2019/20 (MoALD, 2021). Tomatoes are typically consumed in a variety of ways around the world. The fruits can be eaten raw in salads, stews, sandwiches, or salsa, while the processed tomato crops can be consumed in juices, pastes, stews, stews, and drinks (Alam et al., 1998). Tomatoes are abundant in vitamins A and C, carotenoids (lycopene and β-carotene), minerals, numerous phytochemicals, and antioxidant compounds that can effectively reduce the risk of heart disease, cancer, and cardiovascular diseases (Wabali et al., 2017). It contributes significantly to daily diets in the form of carotenoids (lycopene), phenolics, and trace amounts of vitamin E (Lenucci et al., 2006). The demand for tomatoes for processing and fresh consumption throughout the year is gradually rising due to factors like urbanization, hotels, tourism, and increased public awareness of nutrition. These factors are opening up opportunities for off-season production (Kafle & Shrestha, 2017). Most tomatoes are grown as spring crops in the mid-hills and as winter crops in the plains (Pokharel, 2021). Tomato farming can boost the income and standard of living for farmers who choose to engage in commercial and peri-urban farming since tomatoes have a high per capita consumption rate in Nepal (Bajracharya et al., 2016). It produces profitable

Cite This Article

Subedi S, Mehta A, Thapa A, Kattel D, Bhattari S S. 2024. Efficacy of Different Concentration of Calcium Chloride on Post-Harvest Quality of Tomato (*Solanum lycopersicum* L.). *Fundamental and Applied Agriculture*, 9(3): 213–219. https://doi.org/10.5455/faa.190035

crops for small- and medium-sized farmers, creating jobs in the production, processing, and supply chain from farm to fork (Teka, 2013).

Tomato fruits are climacteric, meaning that as they ripen, they become extremely perishable. Tomato fruit typically has a one and a half-week shelf life after harvest, and quality control both during and after harvest is difficult (Safari et al., 2020). In many developing nations, there are significant postharvest losses of tomato fruits. These losses can be attributed to a variety of factors, including ineffective postharvest handling techniques, poor agronomic practices, improper harvesting stages, inadequate transportation facilities, unfavorable storage conditions, and insect infestations (Emana et al., 2017). Physiological deterioration, the effects of oxidation processes, and the lack of practical postharvest treatments that can reduce deterioration during storage are the main barriers to tomato fruit postharvest shelf life and quality maintenance (Eça et al., 2014). Tomato quality may suffer as a result of harvest maturity, which can also have an impact on postharvest fruit quality factors like taste, firmness, and shelf life (Tolasa et al., 2021). The tomato fruit's maturity level at harvest is a crucial factor in determining a number of desirable characteristics (Beckles, 2012).

The vital plant nutrient calcium (Ca) increases the firmness of the fruit, reduces physiological disorders, delays the process of color development, and prolongs the fruit's shelf life under storage conditions, all of which contribute to the improvement of the physical and physiological quality attributes of tomato fruits (Abbasi et al., 2013). The association of calcium ions (Ca^{2+}) was thought to regulate a number of physiological and biochemical processes in tomato fruits by lowering the rate of respiration and ethylene production as a result of rising Ca^{2+} levels in the fruit matrix (Mishra & Prakash, 2018). As a result, fruits that were sprayed with calcium chloride after harvest displayed increased firmness, decreased respiration, and a decreased rate of ethylene, thus delaying the senescence process (Shiri et al., 2016).

Postharvest technology is very important for maintaining and extending the shelf life of perishables and reducing food losses by reducing temperature, and modifying the atmosphere, or applying chemical treatments. These serve to reduce respiration rates, retard ripening, decrease ethylene production, and consequently retard senescence, prevent dehydration, and extend the shelf life, thus preserving produce quality. The tomato fruits at the breaker stage with $CaCl_2$ application extended the shelf life by producing the least amount of ethylene, decreasing respiration rate, and stopping weight loss, according to the application of different concentrations (0.0%, 2.0%) of $CaCl_2$ (Arthur et al., 2015). Tomato fruits treated with $CaCl_2$ had a longer shelf life in storage due to a significant reduction in ethylene production and respiration rate by decreasing physiological weight loss (Tolasa et al., 2021). Both calcium chloride ($CaCl_2$) and calcium lactate have been identified as viable options for prolonging the post-harvest shelf life of tomatoes. Utilizing post-harvest applications of $CaCl_2$ is not only cost-effective but also environmentally friendly, making it easily adaptable for tomato growers at any skill level. Thus, this study aims to explore the impact of post-harvest applications of calcium chloride, minimize post-harvest losses and maximize the quantitative and qualitative parameters of tomatoes.

2. Materials and Methods

2.1. Description of the experimental site

The experimental farm was selected at the Regional Agriculture Research Station, Nepal Agriculture Research Council (NARC), Tarahara Sunsari, for the postharvest treatment of tomatoes. The experiment was conducted to prolong the shelf life of tomatoes by using calcium chloride at different concentrations in the horticulture laboratory from February 16 to March 11, 2023. The experimental site lies at a longitude of 87° 17′ 0″ E and a latitude of 26° 42′ 0″ N at an elevation of 139 meters above sea level.

2.2. Experimental setup and treatment design

Tomato fruits at the breaker stage were harvested from the research field. In the laboratory, undamaged fruit without defects were randomly selected and distributed among the treatments. Fruits were dipped in distilled water and different concentrations of calcium chloride, viz., 0.5%, 1%, 1.5%, 2%, 2.5%, and 3% and 0% distilled water as a control for fifteen minutes. After that, all of the treated fruit was left to air dry on an open tray for 30 minutes at room temperature. Each tray was considered a treatment. Following that, 30 fruits per treatment were placed in cardboard boxes and kept for 12 days at 20°C. Thirdly, fruit was stored at room temperature for a period of 0–7 days during the data collection period. Destructive and non-destructive samples were prepared for each treatment. Out of 30 tomatoes included in the tray, five were tagged as non-destructive samples and used for weight loss observation, whereas the remaining tomatoes were taken as destructive and used for observation of TA, TSS, pH, and juice recovery percentage at every two-day interval after postharvest treatments. The experiment was laid out in a completely randomized design (CRD) with seven different treatments, and each treatment was replicated three times as shown in (Table 1).

Table 1. Details of the experimental treatments

Treatments	Concentrations (%)
T_1: Calcium Chloride	0.5
T_2: Calcium Chloride	1.0
T_3: Calcium Chloride	1.5
T_4: Calcium Chloride	2.0
T_5: Calcium Chloride	2.5
T_6: Calcium Chloride	3.0
T_7: Distilled Water	0

2.3. Observed parameters

During the postharvest life, the following postharvest variables were determined:

2.3.1. Storage conditions

Temperature and relative humidity (RH) during storage were monitored using a temperature-RH measuring device. A digital recording device (digital hygrometer thermometer) was used for this purpose. The average mean temperature was recorded to be 20±2 °C and RH 60±2%.

2.3.2. Physiological loss in weight (PLW) percentage

It was calculated as a percentage weight loss from the initial weight. The initial weight of each sample per replication was taken. In two days, the weight of the sample was taken after setting up the experiment. Weight loss was achieved with the help of a digital balance, which has the capacity to weigh from 0.5 mg to 5 kg.

The weight loss was calculated according to the formula:

$W_1 = [(W_o - W_t) / W_o] \times 100\%$

Where, W_1 is the percentage weight loss, W_o is the initial fruit loss, and W_t is the weight of fruit at the designed time

2.3.3. Total soluble solid (°Brix)

The total soluble solid was determined with the help of a handheld refractometer. Two to three drops of juice were taken from a 5-ml plastic dropper on the refractometer.

2.3.4. Juice recovery percentage

The tomato juice was extracted by squeezing manually. The volume of juice was measured in milliliters by the beaker. The juice percentage per fruit was calculated using the formula:

Juice % = [Juice weight per fruit / Individual fruit weight] ×100%

2.3.5. Acidity

An instrument called a pocket Brix-Acidity Meter Master Kit was used to determine acidity. This device showed the acidity automatically by taking two to three drops of juice from it.

2.3.6. pH of fruit juice

The pH of fruit juice was measured by using a digital pH meter placed on the juice for two minutes.

2.4. Statistical analysis

After the qualitative and quantitative data was recorded in the horticulture lab of NARC at an interval of 2 days up to the 16th day. All the data was entered into a Microsoft Excel sheet and analyzed using R-Studio version 4.2.2. Data were analyzed statistically by performing an analysis of variance, and means were separated using Duncan's multiple range test at the 5% level of significance.

3. Results and Discussion

3.1. Physiological loss in weight (PLW)

The physiological loss in weight (PLW) was found to significantly increase with increasing the storage period in all treatments up to the 16th day. The trend of increasing weight loss percentage was observed at its maximum in control. Tomatoes treated with 3% calcium chloride exhibited consistently minimal weight loss, ranging from 2.01% on the 2nd day to 12.65% on the 16th day of storage. In contrast, untreated tomatoes (control) and those treated with lower concentrations of calcium chloride (0.5%, 1%, and 1.5%) experienced higher and statistically comparable weight losses throughout the storage period (Table 2).

Calcium contributes to the strength and rigidity of the membrane by binding poly-galactonic acid to itself (Devkota et al., 2019). This minimum weight loss in the calcium chloride (3%) treated fruits might be due to retardation in the processes of transpiration and respiration (Joshi et al., 2020). Our results argue with the findings of (Mahajan et al., 2011; Sharafi et al., 2011) who reported that 2% application of $CaCl_2$ resulted in lower weight loss when compared with fruit treated with 3% $CaCl_2$. The tomatoes treated with calcium chloride at 3% concentration might have been effective in reducing the weight loss. The fruit's cell wall's ability to form a network between calcium and pectin to prevent moisture loss may be the cause of the reduced weight loss seen in $CaCl_2$-treated fruit (Tessema, 2013). A similar result was obtained by Bhattarai & Gautam (2006), that calcium may have postponed tomato fruit senescence as well as the rate of transpiration and respiration.

3.2. Total soluble solid (TSS)

TSS is one of the indicators that determines the quality of tomatoes. The TSS content increases significantly in all treatments with the advancement of storage time from the 2nd to the 16th days of storage. The trend of increasing the TSS was observed at its maximum in the untreated group. The fruit treated with 3% calcium chloride consistently exhibited the minimum total soluble solid (TSS) throughout the storage period, ranging from 4.83 °Brix on the 2nd day to 5.47 °Brix on the 16th day. The untreated control and tomatoes treated with lower concentrations of calcium chloride (0.5%, 1%, 1.5%, and 2%) showed higher TSS levels, with the control registering the maximum at 4.96 °Brix, and all were statistically comparable, as indicated in Table 3.

The results are in agreement with Matsunyane, (2022) and Moradinezhad et al. (2020) who reported that the highest soluble solid values were found in control samples of 'Chinese' jujube fruit and the lowest in 1% calcium chloride treatment. Pila et al. (2010) also reported that dipping 'Duke' tomato fruit in a calcium solution decreased the total soluble solids. Fruit treated with calcium chloride may have lower TSS because of slower synthesis, respiration, and metabolite uptake in the fruit tissue (Pila et al., 2010). TSS increases with maturity and ripening (Kader, 2008). The balance between anabolic and catabolic processes is what causes the soluble sugars in fruits and vegetables that are stored to change (Sánchez-Mata et al., 2003). Changes in the soluble solids content of tomatoes are associated with modifications in the hydrolysis of polysaccharides, such as hemicellulose and pectin (Chacon et al., 2017). The faster rate of TSS increases in control and calcium chloride (0.5%) is due to faster metabolic activities through respiration and transpiration. Parmar and Chundawat (1985), reported in earlier research that the increase in TSS of mango fruits is attributed to the hydrolysis of starch into sugars.

3.3. Juice recovery percentage

The juice content was found to significantly decrease in all treatments from the 2nd day to the 16th day of storage with the advancement of the storage period. The juice content in the control was found to be minimal. The maximum loss of juice content was observed in control from the 2nd day (36.23% to the 16th day (15.9% whereas the minimum loss of juice was observed in 3% calcium chloride from the 2nd day (38.55%) to 22.64% on the 16th day, which is on par with calcium chloride (2.5%) and calcium chloride (2%) as in Table 4.

The trend toward a decrease in juice percentage during storage might be due to a loss of moisture from the surface of the fruits (Thapa et al., 2020). White and Broadley (2003) reported that fruits treated with calcium might be more firm because the calcium builds up in the cell walls, allowing the pectic polymers to cross-link, strengthen the walls, and promote cell cohesion. This loss of control over firmness may be caused by a sudden increase in ethylene production and respiration as a result of the tomato's climacteric nature, which increases the amount of water that transpires through the fruit's surface and causes the fruit to shrivel (Bhattarai and Gautam, 2006).

3.4. pH

With increasing the storage period, the pH of tomatoes was found to non-significantly decrease from the 2nd day to the 16th day. The maximum decrease in pH was found in the control. None of the treatments had any significant effect on the pH of tomatoes on the 2nd to 4th days. After 6 days, tomatoes that were untreated showed a significant decrease in pH (4.2 to 4.32). Similarly, other treatments showed the same pattern of pH value, slightly decreasing from the 2nd to 16th days of storage. The tomatoes treated with 3% calcium chloride showed the lowest pH from the 2nd day (4.14) to the 16th day (4.27), which is on par with calcium chloride (2.5%) and calcium chloride (2%) as shown in Table 5.

The primary acids present in most ripe fruits are malic and citric acids, which are lost when fruit becomes more acidic (Etienne et al., 2013). The pH of the chemically treated fruit was found to be lower than that of the control set. This could be attributed to variations in the altered atmosphere produced by various treatment methods (Pila et al., 2010). The fluctuation of pH might be due to variations in titratable acidity or temperature of storage. Citric acid glyoxalase activity increased during ripening, which led to a decrease in acidity (Devkota et al., 2019). Ripening corresponds to the conversion of starch and acids to sugar, and calcium chloride, an ethylene inhibitor, actively participates in this process in tomatoes (Oliu et al., 2011). The possible reason for the decrease in acid content could be their transformation into sugars and subsequent use in the metabolic process while being stored (Rathore et al., 2007). Bhandari et al. (2020) reported that the decrease in pH indicates the increased acidity of the fruit, and this might be due to the formation of acidic compounds due to the degradation of reducing sugars.

3.5. Acidity (A %)

With the advancement of the storage period, the acidity trend was found to be significantly decreasing in all treatments from the 2nd day to the 16th day of storage. The acidity in the control was found to be minimal, and 3% $CaCl_2$ shows maximum acidity. The control group exhibited the highest acidity loss, ranging from 1.29 on the 2nd day to 0.56 on the 16th day. Conversely, the 3% calcium chloride treatment demonstrated the least juice loss, decreasing from 1.34 on the 2nd day to 0.72 on the 16th day, comparable to the effects observed with the 2.5% and 2% calcium chloride treatments, as shown in Table 6.

Citric, malic, and ascorbic acid variations cause changes in TA. It is known that during ripening, the concentrations of these acids decrease (Medlicott & Thompson, 1985). The use of acid in the tricarboxylic acid cycle during the respiration process is most likely what caused the acidity to trend downward during the storage period. The primary cause of the variation in total titratable acids during storage was the metabolic processes of living tissues, which result in the depletion of organic acids (Devkota et al., 2019). $CaCl_2$ is reported to be an ethylene inhibitor, and ethylene plays an active role in the tomato ripening process. Ripening is also associated with the conversion of starch and acids to sugar (Tessema, 2013). Calcium chloride application may slow down fruit metabolism by lowering ethylene production and respiration rate, which lowers TA (Moradinezhad et al., 2019).

Table 2. Effect of calcium chloride ($CaCl_2$) on physiological loss in weight of tomato (%)

Treatment	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day
$CaCl_2$ (0.5%)	2.293^{b}	3.813^{b}	5.05^{b}	8.14^{ab}	9.84^{ab}	11.62^{ab}	13.39^{ab}	15.82^{ab}
$CaCl_2$ (1%)	2.203^{b}	3.923^{b}	5.23^{b}	7.17^{bc}	9.39^{ab}	10.72^{bc}	13.08^{abc}	14.73^{abc}
$CaCl_2$ (1.5%)	2.167^{b}	3.033^{c}	4.79^{bc}	7.31^{bc}	8.9^{bc}	10.62^{bc}	12.54^{bcd}	14.5^{bc}
$CaCl_2$ (2%)	2.15^{b}	2.783^{c}	4.29^{c}	6.88^{cd}	8.49^{bcd}	10.48^{bcd}	11.97^{bcd}	13.96^{bc}
$CaCl_2$ (2.5%)	2.037^{b}	2.503^{c}	3.4^{d}	5.89^{d}	7.83^{cd}	9.99^{cd}	11.51^{cd}	13.57^{c}
$CaCl_2$ (3%)	2.01^{b}	2.537^{c}	3.29^{d}	5.84^{d}	7.31^{d}	8.91^{d}	10.95^{d}	12.65^{c}
Control (Water)	2.773^{a}	4.797^{a}	6.59^{a}	9.03^{a}	10.76^{a}	12.45^{a}	14.47^{a}	16.83^{a}
LSD(0.05)	0.4356	0.5785	0.747	1.567	1.436	1.614	1.709	2.116
SEM(±)	0.061	0.109	0.182	0.436	0.672	0.849	0.953	1.46
F-Probability	*	***	***	***	**	**	**	*
CV	11.137	9.88	9.15	9.192	9.18	8.625	7.77	8.3
Grand Mean	2.233	3.344	4.664	7.182	8.931	10.686	12.558	14.579

Means with the same letter (letters) within the column do not differ significantly at p=0.05 by DMRT, SEM = Standard error of means, LSD=Least Significant Difference, CV=Coefficient of variance, NS, *, ** indicate non-significant and significant at P<0.05 and significant at P<0.01 respectively.

Table 3. Effect of calcium chloride ($CaCl_2$) on TSS (total soluble solids) of tomato in °brix

Treatment	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day
$CaCl_2$ (0.5%)	4.83^{a}	4.9^{ab}	4.97^{ab}	5.03^{b}	5.13^{b}	5.3^{b}	4.37^{b}	5.47^{b}
$CaCl_2$ (1%)	4.9^{a}	4.8^{b}	4.87^{b}	5.00^{b}	5.13^{b}	5.27^{b}	5.37^{b}	5.43^{b}
$CaCl_2$ (1.5%)	4.8^{a}	4.83^{ab}	4.93^{b}	5.00^{b}	5.07^{bc}	5.23^{b}	5.33^{b}	5.43^{b}
$CaCl_2$ (2%)	4.73^{ab}	4.77^{b}	4.87^{b}	4.97^{b}	5.1^{b}	5.27^{b}	5.33^{b}	5.4^{b}
$CaCl_2$ (2.5%)	4.83^{a}	4.8^{b}	4.83^{b}	4.93^{b}	5.03^{bc}	5.20^{b}	5.3^{b}	5.33^{b}
$CaCl_2$ (3%)	4.46^{b}	4.57^{c}	4.63^{c}	4.73^{c}	4.87^{c}	5.03^{c}	5.1^{c}	5.13^{c}
Control (Water)	4.96^{a}	5^{a}	5.1^{a}	5.23^{a}	5.37^{a}	5.47^{a}	5.67^{a}	5.77^{a}
LSD(0.05)	0.286	0.175	0.162	0.183	0.209	0.143	0.143	0.162
SEM(±)	0.0267	0.01	0.0086	0.01095	0.0143	0.0067	0.0067	0.00857
F-Probability	*	**	**	**	**	***	***	***
CV	3.409	2.079	1.895	2.099	2.344	1.55	1.525	1.707
Grand Mean	4.79	4.81	4.89	4.986	5.1	5.267	5.35	5.42

Means with the same letter (letters) within the column do not differ significantly at p=0.05 by DMRT, SEM = Standard error of means, LSD=Least Significant Difference, CV=Coefficient of variance, NS, *, **, *** indicate non-significant and significant at P<0.05, significant at P<0.01and significant at P<0.001 respectively.

Table 4. Effect of calcium chloride ($CaCl_2$) on juice content % of tomato

Treatment	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day
$CaCl_2$ (0.5%)	37.57^{b}	34.28^{bc}	31.7^{bc}	29.18^{bc}	26.39^{b}	24.16^{b}	21.98^{a}	19.88^{b}
$CaCl_2$ (1%)	38.09^{ab}	35.54^{ab}	31.73^{b}	29.31^{bc}	26.48^{b}	24.91^{ab}	22.31^{a}	20.06^{ab}
$CaCl_2$ (1.5%)	38.18^{ab}	35.93^{ab}	33.76^{ab}	31.58^{ab}	28.913^{a}	26.54^{ab}	23.73^{a}	21.76^{ab}
$CaCl_2$ (2%)	38.46^{ab}	36.7^{a}	34.97^{a}	32.04^{a}	28.91^{a}	26.59^{ab}	24.04^{a}	22.04^{ab}
$CaCl_2$ (2.5%)	38.64^{a}	36.84^{a}	35.01^{a}	32.26^{a}	29.03^{a}	26.66^{a}	24.48^{a}	22.36^{ab}
$CaCl_2$ (3%)	38.65^{a}	37.16^{a}	35.18^{a}	32.33^{a}	29.13^{a}	26.69^{a}	24.52^{a}	22.64^{a}
Control (Water)	36.23^{c}	33.42^{c}	29.13^{c}	25.5^{d}	22.31^{c}	20.35^{c}	18.356^{b}	15.9^{c}
LSD(0.05)	1.049	1.866	2.592	2.397	2.152	2.473	2.742	2.727
SEM(±)	0.359	1.135	2.19	1.87	1.5098	1.994	2.452	2.424
F-Probability	**	**	**	***	***	***	**	**
CV	1.577	2.98	4.476	4.516	4.499	5.6198	6.875	7.535
Grand Mean	37.976	35.695	33.07	30.31	27.309	25.127	22.77	20.66

Means with the same letter (letters) within the column do not differ significantly at p=0.05 by DMRT, SEM = Standard error of means, LSD=Least Significant Difference, CV=Coefficient of variance, *, **, *** indicate significant at P<0.05, significant at P<0.01and significant at P<0.001 respectively.

Table 5. Effect of calcium chloride ($CaCl_2$) on pH of Tomato

Treatment	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day
$CaCl_2$ (0.5%)	4.15^{a}	4.16^{ab}	4.18^{bc}	4.21^{b}	4.23^{b}	4.26^{b}	4.28^{ab}	4.30^{ab}
$CaCl_2$ (1%)	4.153^{a}	4.17^{ab}	4.183^{abc}	4.20^{b}	4.22^{b}	4.256^{b}	4.27^{bc}	4.29^{bc}
$CaCl_2$ (1.5%)	4.153^{a}	4.17^{ab}	4.19^{ab}	4.20^{b}	4.22^{b}	4.253^{b}	4.27^{bc}	4.29^{bc}
$CaCl_2$ (2%)	4.14^{a}	4.16^{ab}	4.187^{abc}	4.20^{bc}	4.216^{bc}	4.253^{b}	4.267^{bc}	4.29^{bc}
$CaCl_2$ (2.5%)	4.14^{a}	4.17^{ab}	4.177^{bc}	4.197^{bc}	4.216^{bc}	4.25^{b}	4.26^{cd}	4.28^{bc}
$CaCl_2$ (3%)	4.14^{a}	4.15^{b}	4.167^{c}	4.18^{c}	4.20^{c}	4.23^{c}	4.24^{d}	4.27^{c}
Control (Water)	4.16^{a}	4.173^{a}	4.203^{a}	4.23^{a}	4.25^{a}	4.28^{a}	4.30^{a}	4.32^{a}
LSD(0.05)	0.0265	0.023	0.0206	0.019	0.018	0.0187	0.0226	0.0236
SEM(±)	0.00023	0.00017	0.00014	0.00012	0.00011	0.00011	0.00017	0.00018
F-Probability	NS	NS	*	**	**	**	**	*
CV	0.365	0.315	0.281	0.26	0.248	0.25	0.302	0.313
Grand Mean	4.147	4.16	4.184	4.2	4.22	4.25	4.27	4.29

Means with the same letter (letters) within the column do not differ significantly at p=0.05 by DMRT, SEM = Standard error of means, LSD=Least Significant Difference, CV=Coefficient of variance, NS, * indicate non-significant and significant P<0.05 respectively

Table 6. Effect of calcium chloride ($CaCl_2$) on acidity (A) % of tomato

Treatment	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day
$CaCl_2$ (0.5%)	1.326^{a}	1.24^{a}	1.13^{b}	0.93^{bc}	0.873^{b}	0.77^{b}	0.72^{a}	0.64^{b}
$CaCl_2$ (1%)	1.33^{a}	1.247^{a}	1.13^{b}	0.94^{b}	0.876^{b}	0.776^{b}	0.71^{a}	0.64^{b}
$CaCl_2$ (1.5%)	1.33^{a}	1.24^{a}	1.133^{b}	0.95^{ab}	0.886^{ab}	0.79^{ab}	0.72^{a}	0.643^{b}
$CaCl_2$ (2%)	1.33^{a}	1.253^{a}	1.147^{ab}	0.96^{ab}	0.89^{ab}	0.80^{ab}	0.74^{a}	0.65^{b}
$CaCl_2$ (2.5%)	1.336^{a}	1.25^{a}	1.15^{ab}	0.98^{a}	0.896^{ab}	0.81^{a}	0.75^{a}	0.69^{ab}
$CaCl_2$ (3%)	1.34^{a}	1.256^{a}	1.157^{a}	0.99^{a}	0.91^{a}	0.82^{a}	0.77^{a}	0.72^{a}
Control (Water)	1.29^{b}	1.207^{b}	1.107^{c}	0.897^{c}	0.84^{c}	0.73^{c}	0.63^{b}	0.56^{c}
LSD(0.05)	0.273	0.0267	0.0213	0.0397	0.0273	0.0399	0.0586	0.055
SEM(±)	0.00024	0.00023	0.00014	0.0005	0.00024	0.0005	0.0011	0.00099
F-Probability	*	*	**	**	**	**	**	**
CV	1.174	1.229	1.069	2.388	1.769	2.898	4.646	4.864
Grand Mean	1.3267	1.242	1.136	0.9495	0.88	0.786	0.72	0.649

Note: Means with the same letter (letters) within the column do not differ significantly at p=0.05 by DMRT, SEM = Standard error of means, LSD=Least Significant Difference, CV=Coefficient of variance, NS, * indicate non-significant and significant P<0.05 respectively

3.6. Post-Harvest Life

Tomato fruits treated with calcium chloride (2.5%) and calcium chloride (3%) showed a maximum postharvest life of 25 days, followed by calcium chloride (2%). Similarly, the minimum span was recorded in control fruits (19 days), followed by calcium chloride (0.5%) (21 days), which is shown in the diagram below. Cheour et al. (1991) found that applying calcium extended the shelf life of strawberries by reducing sugar accumulation, decreasing organic acid levels, raising the color saturation index, and promoting the growth of mold, which further justifies our result.

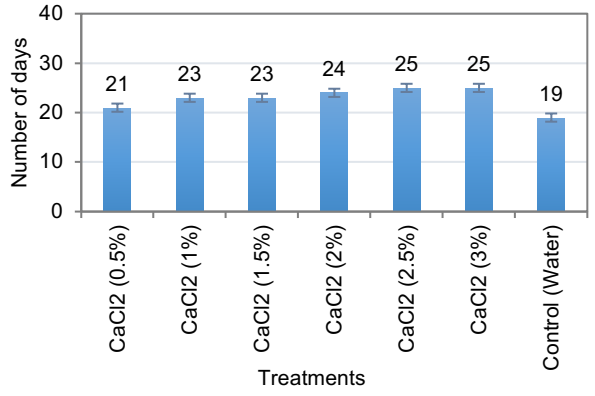

Figure 1. Calcium Chloride ($CaCl_2$) treatment of the shelf-life of tomato

4. Conclusion

Using varying concentrations of calcium chloride could prolong the shelf life of tomato fruit and preserve its quality better than not using them. It was observed that calcium dips slowed down metabolism, as seen by the calcium-treated samples' decreased respiration rates. Calcium chloride at 3% concentration was found to be the most effective in reducing the physiological loss in weight (12.65%), highest acidity (0.2%), lowest pH (4.27), lowest TSS (5.13 °brix), and highest juice recovery (22.64%). This study revealed that tomatoes treated with 3% concentrated calcium chloride showed long shelf life and quality when stored for 16 days at a temperature of 18–22 °C and an RH of 60–70%. Furthermore, tomatoes treated with calcium chloride had an extended shelf life and quality for 16 days compared to those left untreated (control), which also helped stabilize market demand.

Acknowledgement

The authors would like to acknowledge Mahendra Ratna Multiple Campus Tribhuvan University (IAAS), the Prime Minister Agriculture Modernization Project (PMAMP), the Regional Agriculture Research Station, Tarahara, and Sunsari for providing an opportunity to conduct this research.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Abbasi, N. A., Zafar, L., Khan, H. A., & Qureshi, A. A. (2013). Effects of naphthalene acetic acid and calcium chloride application on nutrient uptake, growth, yield and post harvest performance of tomato fruit. *Pak. J. Bot*, *45*(5), 1581-1587.

Alam, K. B., Banu, S. P., & Shaheed, M. A. (1998). Occurrence and significance of spot blotch in Bangladesh. *Spot Blotch and Tan Spot*, 63.

Arthur, E., Oduro, I., & Kumah, P. (2015). Postharvest quality response of tomato (*Lycopersicon esculentum*, Mill) fruits to different concentrations of calcium chloride at different dip-times. *American Journal of Food and Nutrition*, *5*(1), 1–8.

Bajracharya, A. S. R., Mainali, R. P., Bhat, B., Bista, S., Shashank, P. R., & Meshram, N. M. (2016). The first record of South American tomato leaf miner, *Tuta absoluta* (Meyrick 1917) (Lepidoptera: Gelechiidae) in Nepal. *Journal of Entomology and Zoology Studies*, *4*(4), 1359–1363.

Beckles, D. M. (2012). Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biology and Technology*, *63*(1), 129–140.

Bhandari, R., Acharya, P., Sapkota, P., Acharya, M., Adhikari, P., & Upreti, R. (2020). Effect Of Post Harvest Treatments On Shelf Life And Quality Of Sweet Orange (*Citrus Sinensis*) In Gaasc, Gokuleshwor, Baitadis. *Tropical Agroecosystems (TAEC)*, *1*(2), 88–91.

Bhattarai, D. R., & Gautam, D. M. (2006). Effect of harvesting method and calcium on post harvest physiology of tomato. *Nepal Agriculture Research Journal*, *7*, 37–41.

Cheour, F., Willemot, C., Arul, J., Makhlouf, J., & Desjardins, Y. (1991). Postharvest response of two strawberry cultivars to foliar application of CaCl2. *HortScience*, *26*(9), 1186–1188.

Devkota, P., Devkota, P., Khadka, R., Gaire, K. R., & Dhital, P. R. (2019). Effects of chemical additives on shelf life of tomato (Solanum lycopersicum) during storage. *Journal of Agriculture and Forestry University*, *3*, 69-76.

Eça, K. S., Sartori, T., & Menegalli, F. C. (2014). Filmes e coberturas comestíveis contendo antioxidantes-uma revisão. *Brazilian Journal of Food Technology*, *17*, 98–112.

Emana, B., Afari-Sefa, V., Nenguwo, N., Ayana, A., Kebede, D., & Mohammed, H. (2017). Characterization of pre-and postharvest losses of tomato supply chain in Ethiopia. *Agriculture & Food Security*, *6*, 1-11. https://doi.org/10.1186/s40066-016-0085-1

Etienne, A., Génard, M., Lobit, P., Mbeguié-A-Mbéguié, D., & Bugaud, C. (2013). What controls fleshy fruit acidity? A review of malate and citrate accumulation in fruit cells. *Journal of Experimental Botany*, *64*(6), 1451–1469.

Joshi, P., Ojha, B. R., & Kafle, A. (2020). Effect of different postharvest treatments on prolonging shelf life of *Citrus reticulata* Blanco. *Nepalese Horticulture*, *14*(1), 1–8.

Kader, A. A. (2008). Flavor quality of fruits and vegetables. *Journal of the Science of Food and Agriculture*, *88*(11), 1863–1868. https://doi.org/10.1002/jsfa.3293

Kafle, A., & Shrestha, L. K. (2017). Economics of tomato cultivation using plastic house: a case of Hemja VDC, Kaski, Nepal. *International Journal of Agriculture, Environment and Biotechnology*, *2*(01).

Lenucci, M. S., Cadinu, D., Taurino, M., Piro, G., & Dalessandro, G. (2006). Antioxidant Composition in Cherry and High-Pigment Tomato Cultivars. *Journal of Agricultural and Food Chemistry*, *54*(7), 2606–2613. https://doi.org/10.1021/jf052920c

Mahajan, B. V. C., Brar, K. S., Ghuman, B. S., & Boora, R. S. (2011). Effect of pre-storage treatments of calcium chloride and gibberellic acid on storage behaviour and quality of guava fruits. *Fresh Produce*, *5*(1), 22–25.

Matsunyane, K. D. (2022). The effect of calcium chloride postharvest dips and concentrations of the improvement of storage and shelf-life of'classic round'tomatoes (*Solanum lycopersicum*, L.) (Doctoral dissertation).

Medlicott, A. P., & Thompson, A. K. (1985). Analysis of sugars and organic acids in ripening mango fruits (*Mangifera indica* L. var Keitt) by high performance liquid chromatography. *Journal of the Science of Food and Agriculture*, *36*(7), 561–566. https://doi.org/10.1002/jsfa.2740360707

Mishra, S., & Prakash, V. (2018). Biochemical changes in calcium chloride treated Hisar Arun (Local) and Kashi Vishesh (Hybrid) cultivars of Tomato fruit. *Current Agriculture Research Journal*, *6*(3), 395.

MoALD. (2021). Statistical information on Nepalese agriculture. Ministry of Agriculture, Livestock and Development. https://moald.gov.np/publication-types/agriculture-statistics/

MOALD. (2020). Statistical information in Nepalese Agriculture. In *Ministry of agriculture and livestock development.* https://www.moald.gov.np/publication/Agriculture%20Statistics

Moradinezhad, F., Ghesmati, M., & Khayyat, M. (2019). Postharvest calcium salt treatment of fresh jujube fruit and its effects on biochemical characteristics and quality after cold storage. *Journal of Horticultural Research*, *27*(2), 39-46.

Moradinezhad, F., Mohammadian Moghaddam, M., & Khayyat, M. (2020). Influence of GA3 and boric acid foliar application on bioactive compounds and quality of pomegranate fruit (*Punica granatum* L.). *Journal of Horticulture and Postharvest Research*, *3*(1-March 2020), 101–114.

Nuhu, M., & Zarami, S. (2023). Concentrations Effect of Calcium Chloride on Post Harvested Physiology in Selected Varieties of Tomato (*Solanum lycopersicum*) Fruit Under Storage. *International Journal of Advancement in Life Sciences Research*, *6*(3), 47–55.

Oms-Oliu, G., Hertog, M., Van de Poel, B., Ampofo-Asiama, J., Geeraerd, A. H., & Nicolai, B. M. (2011). Metabolic characterization of tomato fruit during preharvest development, ripening, and postharvest shelf-life. *Postharvest Biology and Technology*, *62*(1), 7–16.

Parmar, P. B., & Chundawat, B. S. (1985, May). Effect of various post-harvest treatments on the physiology of Kesar Mango. In *II International Symposium on Mango 231* (pp. 679-684).

Pila, N., Gol, N. B., & Rao, T. R. (2010). Effect of post harvest treatments on physicochemical characteristics and shelf life of tomato (*Lycopersicon esculentum* Mill.) fruits during storage. *American-Eurasian Journal of Agricultural and Environmental Sciences*, *9*(5), 470–479.

Pokharel, A. (2021). Economic analysis of offseason tomato production in Kathmandu, Nepal: A Study of Nepalese tomato growers.

Rathore, H. A., Masud, T., Sammi, S., & Soomro, A. H. (2007). Effect of storage on physico-chemical composition and sensory properties of mango (*Mangifera indica* L.) variety Dosehari. *Pakistan Journal of Nutrition*, *6*(2), 143–148.

Rijal, R. K., Poudel, D., Lamichhane, P., & Gaire, K. R. (2018). Effect and Control measures adopted for Tomato Leaf Miner (*Tuta absoluta*) in Nuwakot, Nepal.

Ruelas-Chacon, X., Contreras-Esquivel, J. C., Montañez, J., Aguilera-Carbo, A. F., Reyes-Vega, M. L., Peralta-Rodriguez, R. D., & Sanchéz-Brambila, G. (2017). Guar gum as an edible coating for enhancing shelf-life and improving postharvest quality of roma tomato (Solanum lycopersicum L.). *Journal of Food Quality*, *2017*(1), 8608304.

Safari, Z. S., Ding, P., Juju Nakasha, J., & Yusoff, S. F. (2020). Combining chitosan and vanillin to retain postharvest quality of tomato fruit during ambient temperature storage. *Coatings*, *10*(12), 1222.

Sánchez-Mata, M. C., Camara, M., & Dıez-Marques, C. (2003). Extending shelf-life and nutritive value of green beans (*Phaseolus vulgaris* L.), by controlled atmosphere storage: Macronutrients. *Food Chemistry*, *80*(3), 309–315.

Sharafi, Y., Shirzadeh, E., & Rabie, V. (2011). Effect of calcium chloride ($CaCl_2$) on postharvest quality of apple fruits. *African Journal of Agricultural Research*, (6 (22).

Shiri, M. A., Ghasemnezhad, M., Fatahi Moghadam, J., & Ebrahimi, R. (2016). Enhancing and Maintaining Nutritional Quality and Bioactive Compounds of "Hayward" Kiwifruit: Comparison of the Effectiveness of Different $CaCl_2$ Spraying Times: Changes of Respiration and Ethylene Production. *Journal of Food Processing and Preservation*, *40*(5), 850–862. https://doi.org/10.1111/jfpp.12663

Teka, T. A. (2013). Analysis of the effect of maturity stage on the postharvest biochemical quality characteristics of tomato (*Lycopersicon esculentum* Mill.) fruit. *International Research Journal of Pharmaceutical and Applied Sciences*, *3*(5), 180–186.

Tessema, G. (2013). Effect of post harvest treatments on storage behavior and quality of tomato fruits. *World Journal of Agricultural Sciences*, *9*(1), 29–37.

Thapa, S., Sapkota, S., & Adhikari, D. (2020). Effect of different postharvest treatments on prolonging shelf life and maintaining quality of sweet orange (*Citrus sinensis* Osbeck.). *Sustainability in Food and Agriculture*, *1*(2), 69–75.

Tolasa, M., Gedamu, F., & Woldetsadik, K. (2021). Impacts of harvesting stages and pre-storage treatments on shelf life and quality of tomato (*Solanum lycopersicum* L.). *Cogent Food & Agriculture*, *7*(1), 1863620. https://doi.org/10.1080/23311932.2020.1863620

Wabali, V. C., Esiri, A., & Zitte, L. (2017). A sensory assessment of color and textural quality of refrigerated tomatoes preserved with different concentrations of potassium permanganate. *Food Science & Nutrition*, *5*(3), 434–438. https://doi.org/10.1002/fsn3.410

White, P. J., & Broadley, M. R. (2003). Calcium in plants. *Annals of Botany*, *92*(4), 487–511.