

Effect of Different Post-Harvest Treatments on Quality and Shelf Life of Tomato (*Lycopersicon esculentum* Mill.) Fruits During Storage

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Abstract

Tomato (*Lycopersicon esculentum* Mill.) is a widely consumed vegetable crop worldwide. The perishability of fruits increased due to the high level of moisture which reduces quality and shelf life. Thus, this study was conducted in Kanchanpur, Nepal from 11th July to 1st August 2022 to investigate the impact of postharvest application of various chemical substances and plant extracts on the post-harvest life of tomatoes throughout the storage. The pink stage of the Heemsohna variety of tomato fruit was harvested and dipped in various treatment solutions; 0.1 % Gibberellic acid (GA₃), 1.5% calcium chloride (CaCl₂), 10% Aloe vera gel, and 15% Neem leaf extract (NLE) or distilled water as control. After that, the fruits were air-dried and kept at ambient temperatures. The experiment was set up using a Completely Randomized Design (CRD) with 3 replications and 5 treatments. At three-day intervals throughout storage, the physicochemical properties and shelf life of tomato fruit were examined. The different postharvest treatments caused the changes in total soluble solids, titratable acidity, decaying loss, and weight loss to be delayed compared to the control. With 0.1% GA₃ and 1.5% CaCl₂, fruit had the lowest decay percentage followed by aloe vera gel and NLE. Similarly, the fruits dipped in 1.5% CaCl₂, had shown maximum shelf life of 21 days. Hence, it was determined that postharvest treatment with GA₃, CaCl₂, Aloe vera gel, and NLE possesses the capacity to keep quality, extend shelf life, and delay spoilage.

Keywords : Calcium chloride, gibberellic acid, physicochemical, post-harvest

Introduction:

Tomato (*Lycopersicon esculentum* Mill. 2n=24) belonging to the family Solanaceae (Ebert, 2020) is grown as an annual plant and the most widely consumed vegetable in the world after potatoes. The tomato is regarded as the most extensively cultivated and processed vegetable in the world, with 186.82 million tons of production and 37.1 t/ha of productivity (FAOSTAT, 2020). Tomatoes are grown on about 22.6 thousand hectares in Nepal, yielding 19.14 mt/ha and a total production of 432,616 mt. The principal districts in Nepal that produce tomatoes are Kavre, Dhankuta, Sarlahi, Dhading, Dang, Kathmandu, and Rupandehi., etc. (MoALD, 2020). Tomatoes are a nutrient-rich food that contains vitamins, minerals, and dietary fibers (Vats et al., 2022). They are edible in a variety of forms, including processed, dried, and fresh

foods (Alam et al., 2007; Beckles, 2012). Lycopene is a polyphenol found in tomatoes that is linked with the prevention of prostate cancer. Similarly, beta carotene also found in tomatoes may help prevent tumor development in prostate cancer (Gong et al., 2016). They are rich in potassium which supports better health by lowering the risk of heart problems (Yang et al., 2011).

Postharvest management practices are advanced and efficient in developed countries which prevent loss after harvest but it is up to 40 % loss in developing countries (Kitinoja et al., 2011). Due to improper harvesting causing mechanical injuries, a sizable portion of the veggies is damaged at the farm gate (Devkota et al., 2014). When it reaches retailers, these losses rise to 30%, and when it reaches consumers, it exceeds 50 %. Therefore, studies on high-quality production and advancements

in handling, packing, storing, and transportation are required (Ghimire et al., 2018). In Nepal due to inadequate equipment at the collection center, inadequate technology, improper handling, packaging, lack of basic amenities at the wholesale market, retailers, and lack of trained manpower in post-harvest handling are major problems causing heavy loss in quantity as well as the quality of tomato (Tiwari et al., 2020).

Materials and Methods:

Sample collection

For the current research Heemsohna (A hybrid variety produced by Syngenta India Private Limited), one of the most significant commercial tomato varieties was selected and collected freshly from a commercial farm located at Bheemdatt municipality, Kanchanpur, Nepal. All fruits thus harvested were transported and carefully handled to the experimental site. The collected fruits were fresh, pink, healthy, evenly proportioned, and devoid of bruising, injuries, and free from disease.

Experimental site

In the agriculture laboratory of Shree Mahendranagar Secondary School, Kanchanpur, Nepal, the experiment was conducted. The experimental site's GPS coordinates are 28° 59' 14.20" N latitude and 80° 9' 54.66" E longitude which is 229 m above sea level. The trial was carried out from 11th July to 1st August 2022. The mean temperature and proportional humidity of the experimental site during this period were 29°C and 66.5 % respectively.

Experimental design and treatment detail

Uniformly sized tomato fruits were chosen and sorted. The design of the experiment was set up in a completely randomized design (CRD) with five treatments and three replications of each treatment. There was a destructible sample for every replication of treatments. 1 gram of gibberellic acid (GA_3) was dissolved in 1000 milliliters (ml) of distilled water to prepare 0.1% GA_3 and 1.5 gm of calcium chloride ($CaCl_2$) was dissolved in 100 ml of distilled water to prepare 1.5% $CaCl_2$. The sample size was 1 kg for every treatment and after treatment fruits were kept on an open tray. After being cleaned with distilled water, the fruits were allowed to air dry before various treatment solutions were applied. Data were taken at 3-day intervals for 21 days. For observation of TSS, pH, and TA fruits were crushed from the destructible samples. Treatment details used in the experiment is given in Table 1.

Preparation of plant extract

Neem leaves were gathered from surrounding and within the school's periphery and then air dried to reduce moisture. Then, a mechanical grinder was used to grind the dried leaves into a fine powder. A 100% concentration of neem leaf extracts (1:1 w/v) was prepared by adding 100 ml of distilled water to 100 g of leaf powder separately and letting it sit overnight. Then, distilled water was

Table 1 : Treatment details used in the experiment at Kanchanpur, Nepal, 2022

S.N.	Treatment number	Treatment detail
1.	T1	Control (Dipped in distilled water for 20 mins)
2.	T2	0.1% Gibberellic Acid (Dipped in 0.1% GA_3 for 20 mins)
3.	T3	1.5% Calcium Chloride (Dipped in 1.5% $CaCl_2$ for 20 mins)
4.	T4	10% Aloe vera gel (Dipped in 10% fresh aloe gel for 20 mins)
5.	T5	15% Neem Leaf Extract (Dipped in 15% NLE solution for 20 mins)

used to dilute the neem leaf extracts to 15% to create the aqueous treatment solutions (Zewdie et al., 2022). According to earlier reports by Navarro et al. (2011), fresh aloe vera gel was prepared. Before longitudinally slicing each leaf to separate the rind from the inner leaf gel, the spikes along its margins were removed. After the gel fillets were crushed, a mucilaginous gel formed, and the fibrous fraction was filtered out. After that, the gel was diluted with distilled water to obtain an Aloe vera 10% (v/v) treatment solution. To apply the treatment, the entire fruit surface received a uniform application of the coating solution and all fruits were allowed to air dry at room temperature for 30 minutes.

Observations

The different parameters recorded were:

Physiological loss in weight (PLW %)

Weight loss from samples was assessed every three days. Fruit weight was measured using a digital sensitive balance. The following formula was used to calculate the weight loss (Devkota et al., 2019):

$$\text{Percentage loss in weight} = \frac{(\text{Initial fresh weight} - \text{Final weight})}{\text{Initial fresh weight}} \times 100$$

Total soluble solid ($^{\circ}$ Brix)

A portable refractometer was used to determine the total soluble solid content in $^{\circ}$ Brix. The tomato flesh was blended to create a sample. After placing one or two drops of clear juice on the refractometer's prism, a direct reading was obtained. The refractometer was calibrated before use by adding a few drops of distilled water. Distilled water was used to wash the prism in between each sample.

Titrateable acidity (TA)

According to Teka (2013), the titration method was used to determine the titrateable acidity of fruit juice. The titrateable acidity was determined in terms of the percentage of citric acid. Using 2 to 3 drops of

phenolphthalein as an indicator, 5 milliliters of tomato juice were titrated against 0.1 N NaOH to determine the juice's TA. It was determined by using the following equation:

$$\text{Titrateable Acidity (\%)} = \frac{(\text{NB} \times \text{VB} \times \text{milliequivalent wt. of citric acid})}{\text{Volume of sample(ml)}} \times 100$$

Where, N_B = Normality of base (0.1N NaOH)

V_B = Volume of the base (ml of NaOH),

Milliequivalent weight (for 0.1 N NaOH) = 0.0064

Spoilage loss

By visually observing fruits exhibiting signs of rotting were considered as spoiled. The decay percentage was computed as the number of decayed fruits divided by the total number of fruits and multiplied by 100.

Shelf life/Storability

Tomato fruit's shelf life was determined by calculating the number of days needed to reach ripeness and then the point at which the fruit could still be sold. Physical appearance and spoilage were major criteria for judgment.

pH

A digital pH meter is used to determine the pH of fruit juice.

Data analysis

Analysis of Variance (ANOVA) was performed on all gathered data after it was entered into an MS Excel sheet. Duncan's Multiple Range Test (DMRT) was used to separate treatment means that differed significantly. Using Gen Stat 15th edition, analysis of variance (ANOVA) and mean comparison by Duncan's Multiple Range Test (DMRT) was carried out.

Results:

Physiological loss in weight (PLW)

As the storage period increased, there was a steady and progressive rise in physiological weight loss. In contrast to that of the control, weight loss of the fruits treated with chemical substances (GA_3 , CaCl_2) and plant extracts (Aloe gel and NLE) was observed to be lower. Throughout the

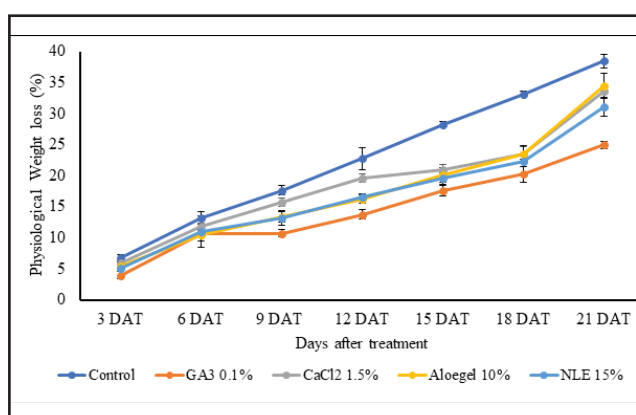


Fig. 1: Effect of different post-harvest treatments on PLW

storage period, the weight loss percentage was minimum in fruits dipped with 0.1% GA_3 ,

maximum weight loss was observed in the control group, and fruits treated with other solutions lie between them. After 21 days of storage, in fruits treated with distilled water (control) 38.46 percent weight loss was observed whereas only 24.93 percent weight loss was noticed in fruits treated with 0.1% GA_3 which is the minimum among all the treatments (Fig. 1).

Spoilage (Decay loss)

In all treatments, the percentage of decay increased gradually and significantly as the storage period was extended. However, there was a difference in the magnitude of spoilage between control and other treatments. The decay percentage of fruits treated with various substances was low as compared to control up to 9th DAT, similar was the case except for fruits dipped in neem leaf extract was slightly higher than other treatments on the 12th DAT. Between the 15th and 21st days after treatment minimum spoilage loss was seen in fruits that had received GA_3 treatment followed by CaCl_2 , Aloe gel, and NLE whereas maximum spoilage loss was in untreated fruits (control group). Similar results were reported by Devkota et al., (2019). The least spoilage (61%) was recorded in fruits treated with 0.1 % GA_3 and 1.5% CaCl_2 whereas untreated fruits had the maximum (92%) spoilage (Fig. 2).

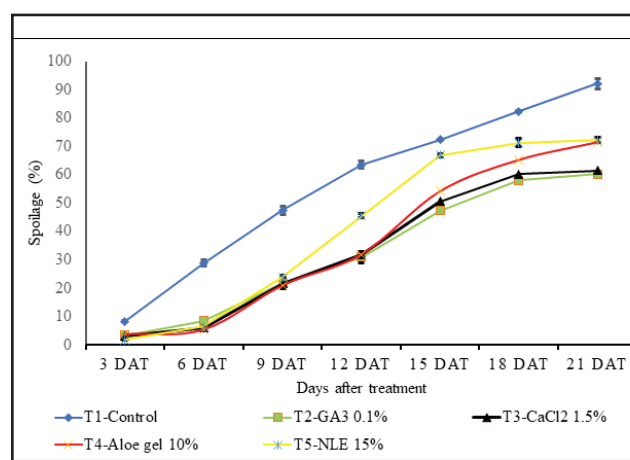


Fig. 2: Postharvest treatment's effect on the spoilage of tomato fruit

Total Soluble Solids (TSS)

Total soluble solids content was increased in control as compared to other postharvest treatments; GA_3 , CaCl_2 , Aloe gel, and NLE (Table 2). There was a minor increase in TSS content as the storage period went on and then declined after 15 DAT. On the 21st day after treatment, the maximum TSS (5.0⁰ Brix) value was found in a control group, whereas the least was recorded in fruits treated with 0.1% GA_3 (4.08⁰ Brix).

Titrateable Acidity (TA)

There was a continuous decrease in the titrateable acidity as the storage period was prolonged (Table 3). On the 3rd day after treatment, the highest TA was observed in

Table 2 : Postharvest treatments effect on TSS content of tomato

Treatments	Total Soluble Solids 0Brix							
	0 DAT	3 DAT	6 DAT	9 DAT	12 DAT	15 DAT	18 DAT	21 DAT
Control	3.83 a	4.03 a	4.23 a	4.63 a	5.00 a	5.1 a	5.00 a	5.00 a
GA3 0.1%	3.27 b	3.43 b	3.63 b	4.30 a	4.47 b	4.53 b	4.28 b	4.08 b
CaCl ₂ 1.5%	3.17 b	3.43 b	3.83 b	4.23 a	4.43 b	4.40 b	4.27 b	4.20 b
Aloe gel 10%	3.3 b	3.47 b	3.70 b	4.20 a	4.40 b	4.52 b	4.37 b	4.28 a
NLE 15%	3.3 b	3.45 b	3.70 b	4.40 a	4.53 b	4.55 b	4.27 b	4.12 b
SE(m)	0.09	0.06	0.09	0.13	0.10	0.06	0.08	0.06
LSD	0.30	0.20	0.39	0.41	0.32	0.19	0.25	0.20
CV (%)	4.90	3.20	5.60	5.20	3.90	2.30	3.20	2.60
Grand mean	3.37	3.56	3.82	4.35	4.57	4.62	4.44	4.34

Means separation in a column followed by the same letters are not significantly different at $p=0.05$, LSD = Least Significant Difference, CV = Coefficient of Variance, DAT- Days after treatment

control which was statistically significant with 15% NLE which has the lowest TA value. Similarly, on the 9th day after treatment, TA was recorded as maximum in control and aloe gel treatments which was significantly different from the minimum value as recorded in 1.5% CaCl₂. Also, on the 15th day after treatments, TA was significantly higher than in other treatments.

Table 3 : Postharvest treatments effect on TA of tomato

Treatments	Titratable Acidity (Citric acid %)							
	0 DAT	3 DAT	6 DAT	9 DAT	12 DAT	15 DAT	18 DAT	21 DAT
Control	0.59	0.58 a	0.57	0.57 a	0.49	0.42 b	0.38	0.37
GA3 0.1%	0.59	0.57 ab	0.57	0.56 ab	0.48	0.44 ab	0.39	0.36
CaCl ₂ 1.5%	0.58	0.58 ab	0.57	0.56 b	0.49	0.43 b	0.39	0.37
Aloe gel 10%	0.59	0.58 ab	0.57	0.57 a	0.49	0.44 ab	0.39	0.35
NLE 15%	0.59	0.57 b	0.58	0.57 ab	0.49	0.45 a	0.39	0.35
SE(m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD	NS	0.01	NS	0.00	NS	0.01	NS	NS
CV (%)	0.80	1.40	0.80	0.80	1.50	2.20	1.80	4.40
Grand mean	0.60	0.57	0.57	0.56	0.49	0.43	0.39	0.36

Means separation in a column followed by the same letters are not significantly different at $p=0.05$, NS= Non-Significant, LSD = Least Significant Difference, CV = Coefficient of Variance, DAT- Days after treatment

pH

The pH value varied throughout the storage period with postharvest treatments (Fig. 3). From day 0 to day 6th there was a slight rise in pH in all the treatments and then a sharp decrease on the 9th day after treatment. Again after the 9th DAT continuous and a slight rise in pH value with minor fluctuations. On day 15th of storage, there was a difference in pH value among NLE and CaCl₂ treatment. On 21 DAT there was a notable distinction in pH value between other treatments, and the control (5.33) being the highest.

Shelf life/ Storability

Fruits treated with 1.5% CaCl₂ had the longest possible shelf life (21 days) followed by 0.1% GA₃ (19 days)

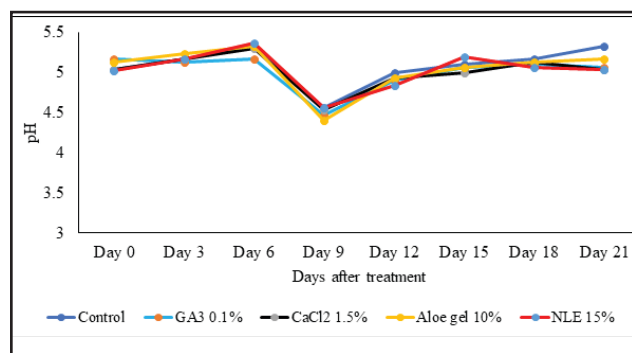


Fig. 3: Postharvest treatment's effect on the pH of tomato fruit

while the control group observed the minimum shelf life i.e., 10 days. CaCl_2 and GA_3 were significant over other treatments to increase the shelf life of tomatoes (Fig. 4). Similarly, in contrast to the control shelf life of fruits was also increased by dipping in Aloe gel (18 days) and NLE (16 days).

Discussion:

There was a positive consequence of different post-harvest treatments on the reduction of weight loss throughout the storage time. During the storage period, CaCl_2 had a notable decrease in the rate of physiological weight loss of the produce which is associated with transpiration and respiration (Bhattarai & Gautam, 2006). Tomato weight loss typically increases over time while being stored but if treated with 1.5% CaCl_2 at the pink stage experienced the least amount of weight loss over

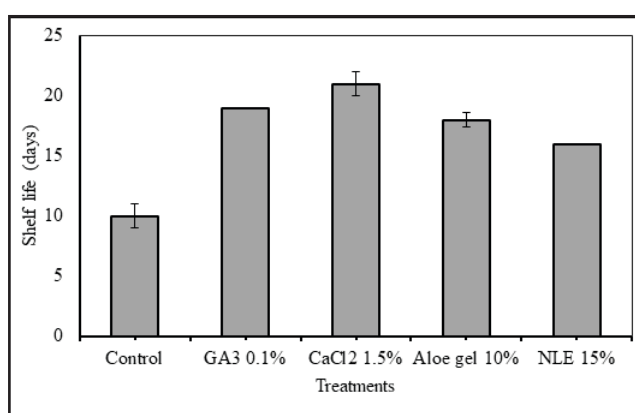


Fig. 4: Postharvest treatments effect on the storability of tomato

the storage duration as stated by Demes et al. (2021). Due to its exceptional ethylene absorbent properties, the fruits treated with CaCl_2 in conjunction with modified atmospheric packaging may have contributed to the extension of the storage period (Genanew, 2013). There was a delay in the ripening of tomato fruits due to GA_3 treatment. This corresponds with the findings of Devkota et al. (2019), who reported that fruits treated with GA_3 , reduce tissue permeability by creating a semipermeable shield that blocks moisture, carbon dioxide, and oxygen, slowing down water loss and respiration, and delaying ripening. Similarly, ethylene production and the activity of peroxidase are reduced along with the slow conversion of starch to sugars (Gol & Rao, 2011). Fruit weight was found to be more effectively maintained by GA_3 (0.1%) and CaCl_2 (1.5%); the same trend was also reported by Demes et al. (2021). There was a reduction in weight loss by dipping in neem leaf extract due to the reduction of chances of fungal growth (Tunwari et al., 2019), and weight loss was also reduced by coating with different concentrations of fresh aloe vera gel which creates a thin layer that prevents from injuries and microbial entries (Chrysargyris et al., 2016).

Demes et al. (2021) stated a similar result of postponing spoilage loss as a result of GA_3 treatment. Possible explanations for this decrease in fruit softening might

be due to the inhibition of ripening or softening-related enzymes, which preserve fruit firmness while it is being stored (Jawandha et al., 2009). As calcium chloride also has a significant impact on delaying ripening and senescence, the incidence of rotting in fruits was reduced (Pila et al., 2010) and fruits will remain favorable for marketing under modified packaging along with calcium chloride treatment (Genanew, 2013). GA_3 also contributes to delaying spoilage by preserving membrane permeability and the integrity of the cell wall by safeguarding against degradation (Kappel & MacDonald, 2002). CaCl_2 and GA_3 treated fruits have significant contributions in lowering decay loss than untreated fruits as these chemicals may have prevented decay loss and decreased the susceptibility of the pathogen (Devkota et al., 2019). As compared to the control, NLE and Aloe vera gel produced noticeable results during storage as stated by Chrysargyris et al. (2016) and Zakki et al. (2017) respectively.

It might be possible that there was a tiny variation in the fruit's ripening stage even though it appeared that they were all in uniform ripening when choosing destructive samples. As maturity and ripening proceed, the TSS value of tomato fruits increases because during the ripening process, starch breaks down into sugars, and pectin is hydrolyzed (Youssef et al., 2012). There was a slow increase in the TSS value of treated fruits as compared with the control this could be because coating slows down the rate at which carbohydrates hydrolyze, thereby limiting the increase in total soluble solids (Roy & Karmakar, 2019). In GA_3 -treated fruits, there was a reduction in TSS, which is associated with delaying the ripening process which was due to the slower respiration and metabolic activity during storage (Pila et al., 2010). According to Devkota et al. (2019), the rise in the total soluble solid content in fruit during storage was due to a change in pectin substances, starch, or polysaccharides into soluble sugars. In postharvest treatments other than control there was an increasing trend in TSS value in the initial storage period and then a decrease in value of TSS after the 15th day of storage. Devkota et al. (2019) noted similar results in tomato fruits during storage. According to Kanmani & Sashidevi (2017), tomatoes coated with pectin showed a slight initial increase in TSS concentration followed by a subsequent decrease.

Throughout the storage period, there was a change in the acidity level that was highest in the control group as compared to other treatments which may be due to slower change in organic acids, slow respiration rate, and metabolic activities due to these postharvest treatments (Devkota et al., 2019). Titratable acidity was reduced by the formation of sugars because of the oxidation of organic acids after fruit ripening. This reduction of acids decreases the desirability of fruits (Genanew, 2013). Shrestha et al. (2018) noted a similar trend of decreasing titratable acidity during storage time in Mango fruit treated with neem leaf extract due to their impact on the use of organic acids in respiration, which inhibited starch

degradation and postponed physiological aging.

The effects of GA₃, CaCl₂, Aloe gel, and NLE on the pH of tomato fruit were varying with days after treatment. The pH of the fruits treated with various substances was found to be lower than that of the control set. This could be attributed to variations in the environmental conditions caused by various treatment solutions (Pila et al., 2010). The studies done by Zewdie et al. (2022) found that either beeswax coating alone or in conjunction with NLE dipping produced a significantly lower pH value than either NLE dipping alone or the control sample. This is most likely related to the change in respiration rate and metabolic activity in tomato fruits treated with bee wax or NLE. The Reduction in pH value in different treatments other than control might result from the conversion of starch, polysaccharides, and pectin into soluble sugars and utilization in the metabolic process during storage (Rathore et al., 2007). The findings of Devkota et al. (2019) are in favor of our findings where similar results of the highest pH value in control after 21 DAT were observed. These statements are in favor of our findings.

Post-harvest life was extended by various treatments including chemical substances and plant extracts. Similar results of extended storage life with CaCl₂ treatment were reported by Jamir & Kwalhring (2017). According to Pila et al., (2010) shelf life was extended by dipping tomato fruits in 0.1% GA₃ solution which was due to the slower reduction in peroxidase activity, ethylene production, and conversion of starch into sugars. These observations of extended shelf life are comparable to the results of Dang et al. (2008) and Zakki et al. (2017). The aloe vera gel coating greatly enhances the shelf life of tomatoes by retaining moisture, reducing decay loss and weight loss percentage, and also acts as a preservative (Roy & Karmakar, 2019). In the study done by Zakki et al. (2017) neem leaf powder can be used as a coating material to increase shelf life and reduce decay by inhibiting the growth of some fungi that cause tomato fruit deterioration.

Conclusion:

This study found that tomato fruit ripening could be effectively delayed by postharvest treatments like GA₃, CaCl₂, Aloe vera gel, and Neem leaf extract and also maintain their overall quality. Compared to untreated fruits, these treatments decreased weight loss, spoiling, and changes in other attributes like pH, TA, and TSS. Tomatoes could have an extended shelf life of up to 21 days with 1.5% CaCl₂ treatment and 19 days with 0.1% GA₃ treatment without compromising quality. The best treatment to preserve quality and extend post-harvest life was 0.1% GA₃. Aloe vera gel and Neem leaf extract also positively impacted shelf life and quality. The study concluded that these postharvest treatments possess the ability to preserve the quality of tomato fruits while extending their shelf life, and additional investigation is required to ascertain the best alternative postharvest

treatments among chemical substances and plant extracts.

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Declaration of conflict of interest and ethical approval:

The authors agree that they don't have any conflict of interest in the published materials. Jagdish Chandra Dhama is engaged in experiment design, laboratory research, data gathering, data processing, and manuscript writing. Dharma Raj Katuwal, Kabi Raj Awasthi, and Karan Singh Dhama took part in the experiment's design, data analysis, and manuscript writing. Before submitting the work to the journal *Nepalese Horticulture*, each author reviewed it. The authors have obtained prior approval, where appropriate, and the current article does not involve any human participants or animals.

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