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RESEARCH PAPER

Effect of essential oil on shelf-life and quality attributes of tomato in Rupandehi, Nepal

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Abstract

Tomato (*Lycopersicon esculentum* Mill) is one of the most consumed vegetables in the world. Chemicals like Bavistin and Calcium Chloride used to enhance the postharvest life of tomatoes have detrimental effects on human health. An experiment was conducted on tomatoes to determine the effects of essential oils on their physical (color, firmness, weight loss) and chemical attributes (TSS, TA, Vitamin C, pH). Tomatoes were treated with different concentrations of lemon grass oil, calcium chloride (1%), and extract of *Justicia adhatoda* (100%), and the effects were analyzed along with the control. No significant difference in weight loss was observed among treatments recording maximum weight in *Justicia* extract treatment (12.86%) and minimum in the control (9.73%). Maximum firmness (5.71 Nmm^{-1}) was recorded in 100% Asuro extract treatment on Day 14 while there was no significant difference in pH on treated tomatoes except on the 10th DAT. A significant difference was noted in TSS, titratable acidity on 4 DAT, and vitamin C content among treatments. TSS content increased up to 10 DAT and showed a gradual diminishing pattern in TSS content in almost all treatments on 12 DAT and 14 DAT where maximum TSS (4.933 Brix) was found in 1% $CaCl_2$ and minimum TSS (3.466 Brix) was found in 200 ppm EO. Furthermore, minimum TA (0.21%) was observed in 200 ppm EO whereas maximum TA was found in tomatoes treated with 100% Asuro extract (0.36) at 14 days after treatment. Additionally, the highest content of Vitamin C (0.276 $mgml^{-1}$) was recorded in tomatoes treated with 200 ppm of essential oil. There was a significant difference ($p < 0.05$) in the TSS/TA ratio among treatments during the experiment where the highest ratio (21.08) was observed in 1% $CaCl_2$ and the lowest ratio (9.92) was obtained in 100% Asuro Extract at 14 days after treatment. The current study implies essential oils are potential alternatives to hazardous chemicals enhancing shelf life and safety for human health. It is advisable to carry out multiple experiments in a broader area using different varieties with various concentrations.

Keywords

Essential Oils, Postharvest Loss, Shelf-life, Tomato, Vitamin C

Introduction

Tomato is a significant vegetable in the world with a global production of 182 million tons of fresh fruit from 5.1 million ha of land led by China, the United States, and India (FAOSTAT 2022). Due to its diverse topography and wide range of climate, Nepal has the potential to produce a wide range of crops throughout the year (Chaurasia et al. 2020). Nepal produces around 410 thousand metric tons of tomatoes from 21,000 ha of land, yielding 19 mt/ha (MOALD

2017/18). Tomatoes contain lycopene which has antioxidant properties and cancer-fighting agents – bioflavonoid, vitamins (Ascorbic acid and vitamin A), and glycoalkaloids (tomatine) (Ayomide et al. 2019). Besides, they also reduce health issues like cholesterol, blood pressure, and cardiovascular diseases, boost immunity, protect against cell damage, regulate blood sugar, strengthen the bones, and so on (Bhowmik et al. 2012). Various steps of the value chain of tomatoes provide employment opportunities boosting the economy of small and medium-sized farmers (Tolasa et al. 2021).

Advanced research and the adoption of technologies like plastic house, and storage, have soared tomato production in recent years in Nepal (Pokharel 2021). Off-season production of tomatoes is increasing. This increase might be due to its nutritional and economic importance as it gives good returns in a short period (Upadhyay et al. 2004). Even though production is increasing, postharvest handling plays a crucial role in meeting the demands of the market. The quality of vegetables is affected by postharvest handling which results in huge losses in the food industry. Being perishable, tomato encounters several problems including insects, pests, and diseases after harvest which reduce their quality and cause losses (Parajuli et al. 2022; Ghimirey et al. 2024). Quality parameters of the tomato include color, size shape, weight, firmness, TSS, pH, Vitamin C, and flavor (Okolie and Sanni 2012). There are many factors behind the post-harvest losses, but in most developing countries mishandling during harvesting, packaging, lack of technology, unavailability of equipment and facilities at collection centers, poor transportation, lack of pre-storage treatment and proper storage facilities, and untrained manpower are the major for post-harvest losses (Tolasa et al. 2021). Among the vegetable crops, tomato is one of the highly perishable commodities. Postharvest loss in vegetables is 25–30%, among which tomato has the highest loss of 33% (Munhuewyi 2012).

Post-harvest facilities and treatments are inadequate like cold storage, different preservatives, heat treatments, etc. Lack of rural infrastructure facilities and poor marketing information are prevailing (Qadri et al. 2020; Acharya et al. 2023; Chaurasia et al. 2023). Excessive use of chemical preservatives harms human health and the environment with high residual toxicity. Also, mechanical damage, physiological deterioration, insects, pests, and diseases are serious problems in post-harvest (Kasso and Bekele 2018). Fully matured tomatoes have a shelf-life of 5–7 days which limits the sales and distribution of tomatoes. To preserve the tomatoes, they are often stored in the refrigerator which eventually affects the tomato flavor and its other qualities (Venkatachalam et al. 2024). Besides, sanitizing agents like chlorine and chlorine-based means are used which might not be able to protect fully, also at the same time they are associated with the production of harmful, carcinogenic compounds (Product et al. 2021). Thus, there is a further need for research on a sustainable approach to increase the shelf-life of tomatoes.

Most Nepalese vegetable growers and traders have limited knowledge about the appropriate postharvest handling, storage, and treatments. So, it is of utmost necessity to identify the appropriate treatments to improve tomatoes' shelf life and postharvest quality (Faqeerzada et al. 2018). The use of chemical compounds degrades human health (Chaudhari et al. 2021). Researchers have prioritized essential oils over others because of their antioxidant, anti-inflammatory, antifungal, and antibacterial properties. Moreover, essential oils have shown promising results for preserving food quality ensuring safety for human consumption(Product et al. 2021). Low-mammalian toxicity, biodegradable properties, and environmentally friendly nature make essential oil a potential alternative to fungicides during postharvest. (Ding and Lee 2019) Thus, this research hypothesized that essential oils will significantly impact the postharvest preservation of tomatoes. The focus of this research was to assess the effect of essential oils on the physicochemical attributes and quality of tomatoes aiming to identify the most viable sustainable way to maintain the postharvest life of tomatoes.

Materials and methods

Experimental details

The research was carried out at the Central lab of IAAS, Paklihawa of Siddharthnagar municipality. Complete Randomized Design (CRD) was used in the experiment. The total number of replications was 3 along with 7 treatments in each replication (Table 1). The Srijana variety of tomatoes was used in this study for 22 days of the research. Srijana variety was preferred as it has various traits preferred by the farmers and benefits from the production and marketing of this variety (Babu et al. 2016). It was chosen as it is a popular hybrid developed by the Horticulture Research Division (HRD) in Nepal preferred by many growers (Chapagain et al. 2011; Gurung et al. 2020). It has greater adaptability, appropriate for off-seasonal cultivation, and has elevated taste with a high potential for international market expansion (Thapa Magar et al. 2016).

Table 1. Treatment and concentration details.

Treatments	Details	Concentration
T1	Lemongrass oil	50 ppm
T2	Lemongrass oil	100 ppm
T3	Lemongrass oil	150 ppm
T4	Lemongrass oil	200 ppm
T5	Calcium chloride dehydrate	1%
T6	*Justicia adhatoda* extract (Asuro)	100%
T7	Control	Without any treatment

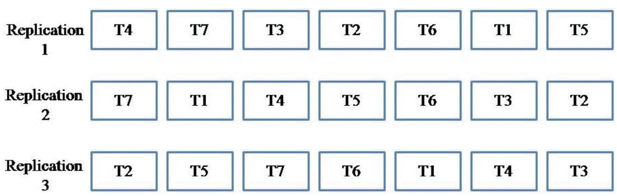

Figure 1. Layout of the treatments with CRD in the horticulture lab of the Institute of Agriculture and Animal Science, Rupandehi, Nepal.

Sample collection

Sample fruits were collected on 30th November 2021 from Nirmala Ekta Wambule Farm situated in Harisiddhi-Lalitpur at the light red stage and transported to the research site, Central Lab, Institute of Agriculture and Animal Science (IAAS), Paklihawa the next morning. Cleaning, manual grading, and visual sorting were done to obtain samples of uniform size, color, and quality. Samples were placed in 2.8 L plastic containers each containing 21 tomatoes and lemongrass oil of various concentrations 50 ppm, 100 ppm, 150 ppm, and 200 ppm, were added and kept sealed using aluminum foil for 8 hours for the treatment. Also, for treatment 5 and 6 tomatoes were dipped in the solution of 1% Calcium chloride and 100% Justicia extract for 30 minutes.

Here, T1 is 50 ppm, T2 is 100 ppm, T3 is 150 ppm and T4 is 200 ppm concentration of lemongrass essential oil. Such concentrations of lemongrass essential oil were used to find out its effectiveness in preserving the quality attributes of tomatoes. Similarly, the different concentrations of lemongrass oil (50 ppm, 100 ppm, 150 ppm, and 200 ppm) were used to examine the gradient of effects. The minimum level of lemongrass oil (50 ppm) was used with an objective to assess the minimum requirement of lemongrass oil to achieve effective results while a higher level (200 ppm) was used to analyze any toxic effect during the postharvest treatment. In vitro, the subsequent colony formation of *Colletotrichum coccodes*, *Botrytis cinerea*, *Cladosporium herbarum*, *Rhizopus stolonifer*, and *Aspergillus niger* are reduced by varying concentrations of lemongrass oil (range from 25 to 500 ppm) ultimately increasing shelf life of tomatoes. Some studies showed the significance of 25 ppm, 100 ppm, 1000 ppm, 2000 ppm, 3000 ppm to 5000 ppm concentrations in preserving the postharvest quality of fruits and as food preservatives (Tzortzakis and Economakis 2007; Azarakhsh et al. 2014; Ibrahim et al. 2017).

Sampling

On the first day of the experiment, 3 tomato samples without any treatment were tested separately for physicochemical evaluation. One tomato sample was taken from each replication of each treatment on the 2nd, 4th, 6th, 8th, 10th, 12th, and 14th days after treatment. Before taking out samples, all 21 tomatoes of an experimental unit were weighed. Individual sample juice was prepared from a slice of 20 g of each tomato sample using a mortar pestle for further physicochemical evaluation. The juice obtained was diluted with 10 ml of distilled water and centrifuged at 10,000 rpm for about 5 minutes.

Parameters of study

The physical [Weight loss (%) and Firmness (Nmm^{-1})] and chemical [pH, Total soluble solid (°Brix), Titratable acidity (%), Vitamin C ($mgml^{-1}$)] attributes of the tomato were measured in each two-day interval up to the 14th day except for weight loss (%). Each treatment was kept in 2.8 L plastic containers each containing 21 tomatoes during the experimental setup. Since 3 tomatoes were taken as samples for weight loss each day when we reached days 12 and 14 only two tomatoes were left so data were not taken as it won't be uniform.

Data collection

Measurement of physiological loss in weight

Kerro Digital Weighing Balance (Scale PI/BL-20001) was used to determine fruit weight as described by Sipahi et al. (2013). The weight of 3 tomatoes from each treatment replication was taken on the day of treatment. Thereafter weight was taken at every two-day interval up to 10 days.

The weight loss was calculated (%) as below:

$$\text{Weight loss percentage} = \frac{w_0 - w_t}{w_0} \times 100$$

where,
W_0 = weight of tomato on the previous day
W_t = weight of tomato on the next day (i.e. day of sampling on 2, 4, 6, 8, and 10th day).

Measurement of firmness

The firmness of the fruit was measured by using a digital penetrometer (Lutron Model Fruit hardness tester model FR 5105). Firmness value was expressed in Nmm^{-1} (Saki et al. 2019).

Measurement of total soluble solid (TSS)

TSS was measured from 3 samples of each replication using a Milwaukee (MA871) digital brix refractometer. 0.2 ml of well-shaken fruit juice was kept on the prism of the refractometer with the help of a micropipette. Then the value of TSS was recorded and expressed as degree brix (°Brix) as explained by Saki et al. (2019).

Measurement of titratable acidity (TA)

Titratable acidity was measured through the titration process. 0.1 N NaOH (sodium hydroxide) as titrant was kept on the burette. A 25 ml of distilled water was taken in a conical flask and 3 ml of sample juice was mixed with it and 2 drops of Phenolphthalein were used as an indicator. Titration was carried out till the appearance of pink color and the corresponding value of NaOH consumed was recorded. The acid percentage was calculated using the following formula (Gotame et al. 2015).

$$\text{Acid}(\%) = \frac{(\text{ml of NaOH used}) \times (0.1\text{N NaOH}) \times [\text{Milliequivalent factor}(0.064)]}{\text{grams of sample}} \times 100$$

Measurement of vitamin C/ascorbic acid

The vitamin C content of the sample juice was measured through a titration process. 2, 6 dichlorophenol-indophenol (DCIP) as a titrant was prepared by dissolving 0.25 gm of sodium salt of DCIP in 500 ml of hot distilled water (Nielsen and Nielsen 2017). Later, the solution was made 1 ltr by adding distilled water in a volumetric flask and letting it cool. The L-ascorbic acid standard solution was prepared by mixing 0.1 gm ascorbic acid in 100 ml oxalic acid (0.5%). Standardization of DCIP solution was carried out by titrating DCIP solution with 1 ml L ascorbic acid standard solution in 25 ml of 0.5% (w/v) oxalic acid. Three titrations were done from each replication of each treatment to make the experiment more precise. The process was carried out until the light rose pink color appeared.

Statistical analysis

Data were entered using MS Excel 2010 sheet. Tabulated data were subjected to Analysis of Variance (ANOVA) to determine if there were any significant differences among the treatments. Thereafter, statistical separation of the means which were significantly different was performed with Duncan's Multiple Range Test ($p < 0.05$). Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) was carried out using R-Studio.

Results and discussion

Weight loss (%)

The pattern of weight loss with advancement of storage period during our research. There was a continuous increase in weight loss percentage as time proceeded forward. However, there was no significant difference in weight loss among treatments, but maximum weight loss was found in Asuro Treatment (12.86%) followed by 100 ppm essential oil treatment (11.44%) and minimum in control (9.73%) as shown in Fig. 2A. This might be due to the increased respiration rate accelerated by the chemicals present in Asuro extract (Acharya et al. 2020).

Fruit shelf life is significantly impacted by moisture loss, and the main cause of fruit weight loss is transpiration, respiration, and dehydration which leads to water loss due to which there will be a difference in water vapor pressure between the fruit's surface and the surrounding air (Suseno et al. 2014; Al-Dairi et al. 2021).

Firmness (Nmm^{-1})

When determining the quality of tomatoes, the two most crucial aspects are their color and firmness. The texture is affected by the firmness of the flesh, and customers may use texture as their ultimate criterion when selecting which tomatoes to buy from a certain batch (Batu 2004). Maximum firmness (5.71 Nmm^{-1}) was observed in 100% Asuro extract treatment followed by control (5.6 Nmm^{-1}) on Day 14 as illustrated in Fig. 2B. This might be due to the antimicrobial property of *Justicia adhatoda* (Asuro). With increasing storage time, the pectin gradually decomposes into soluble pectin, which decreases firmness. In addition, the hydrolysis and consumption of starch in tomatoes promote their softening (Yin et al. 2019). Moisture loss through transpiration and enzymatic changes can lead to decreased firmness in tomatoes. Various factors such as reduced cell turgor pressure and degradation of cell walls and polysaccharides play important roles in firmness reduction (Al-Dairi et al. 2021).

pH

The pattern of pH value changes over time is shown in Fig. 3A. No significant difference in pH was observed on treated tomatoes except on the 10^{th} DAT. Maximum pH was observed in 200 ppm EO (4.720) tomatoes followed by 150 ppm EO (4.653) whereas minimum was observed in 100 ppm EO (4.403). Teka (2013) reported the minimum and maximum pH values of fruit samples in mature green and full ripen stages respectively. Similar results were also reported by Borji and Jafarpour (2012) that the pH of tomato fruit will increase with advancement in the maturity stage from mature-green to full-ripe stage.

Titratable acidity (%)

From Fig. 3B, we came to conclude that there is a significant difference in tritatable acidity (TA) on tested tomato 4 DAT. The value of TA decreases continuously along the advancement of the experimental period. Minimum TA (0.21%) was observed in 200 ppm EO followed by 1% $CaCl_2$ (0.23) whereas maximum TA was found in tomatoes treated with 100% Asuro extract (0.36) at 14 days after treatment. Higher respiration rate as ripening progresses, when organic acids are used as a substrate in respiration, could be linked to higher titratable acidity loss over storage duration (Yebirzaf and Kassaye 2018). A similar result was reported by Teka (2013) that acid content decreases gradually with advanced ripening.

Total soluble solid (°Brix)

Total soluble solids (TSS) are a measure of the ripening process, the amount of sugar and soluble minerals that are present in fresh food, and how well the fruit tastes (Abiso et al. 2015). From the table, we came to conclude that there is an increment in TSS content of tomatoes up to 10 DAT, and a gradual diminishing pattern in TSS content was observed in almost all treatments on 12 DAT and 14 DAT. Maximum TSS (4.933 Brix) was found in 1% $CaCl_2$ followed by control (4.033) whereas minimum

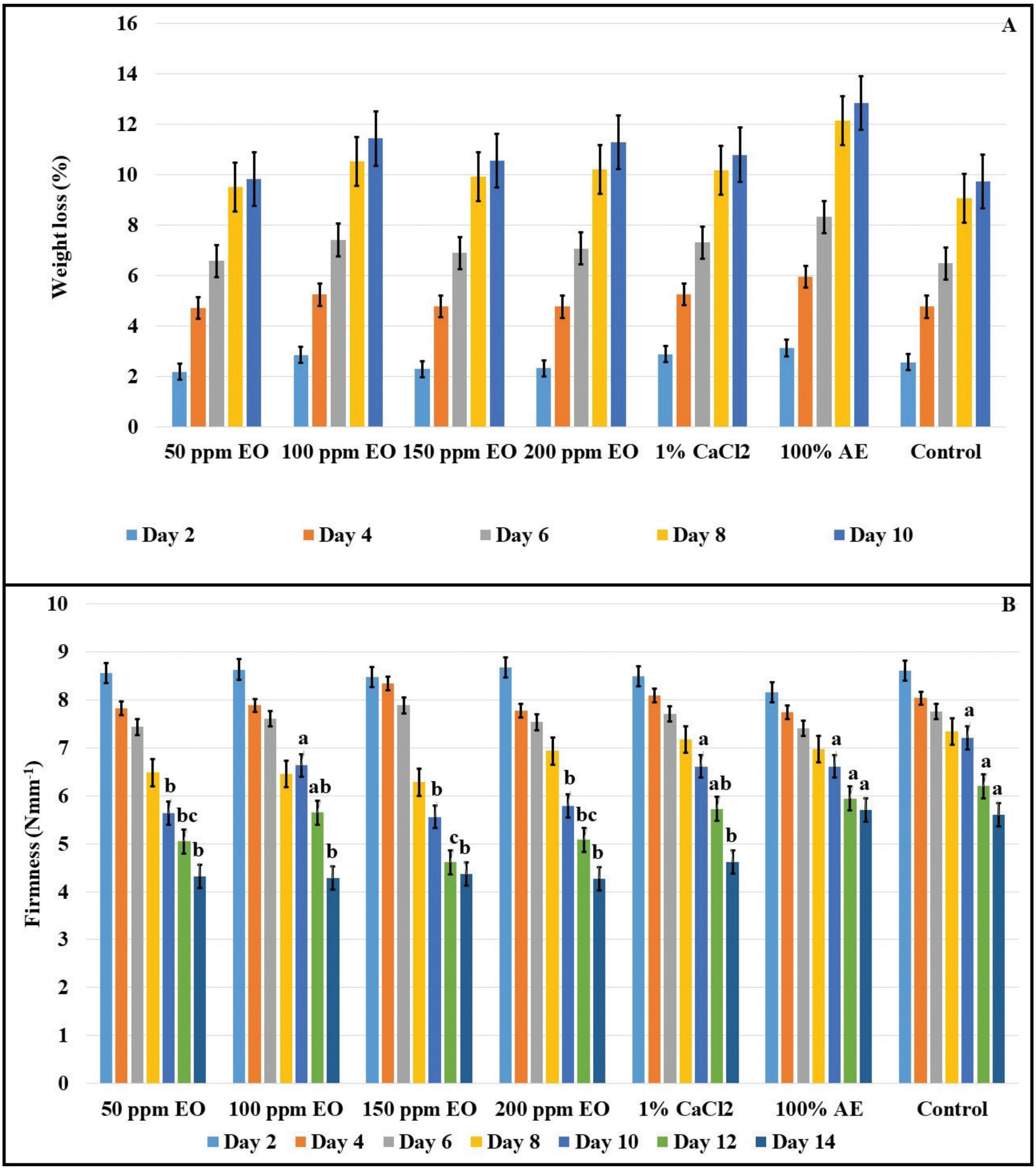

Figure 2. Effect of postharvest treatments on Weight loss (**A**) and Firmness (**B**) during the lab experiment in 2021.

TSS (3.466 Brix) was found in 200 ppm EO (Fig. 4A). According to Moneruzzaman et al. (2009), the total sugar and TSS content of mango fruits rose as they ripened and were stored. The conversion of starch into sugars may be the cause of the rise in the overall sugar level.

Several studies have shown a significant increase in TSS during ripening which is due to moisture loss thus resulting in high concentration as well as the hydrolysis of carbohydrates to soluble sugar (Nath et al. 2012; Tigist et al. 2013). Similarly, a lower increasing trend of TSS content treated with treatment might be possibly due to delayed ripening that resulted in lesser conversion of carbohydrates (Islam et al. 2013).

Vitamin C (mgml^{-1})

A significant difference in Vitamin C content among treatments was found during the experiment. Vitamin C content kept increasing up to the 8th day and decreased on successive days. The highest content of Vitamin C (0.276 mgml^{-1}) was observed in tomatoes treated with 200 ppm of essential oil (Fig. 4B). This is possibly due to the reason that higher concentrations of lemongrass oil block the oxygen from the external environment, inhibit the activity of ascorbates, and delay the oxidation of vitamins (Yin et al. 2019). While most fruits and vegetables experience a gradual decline in vitamin C over time, some

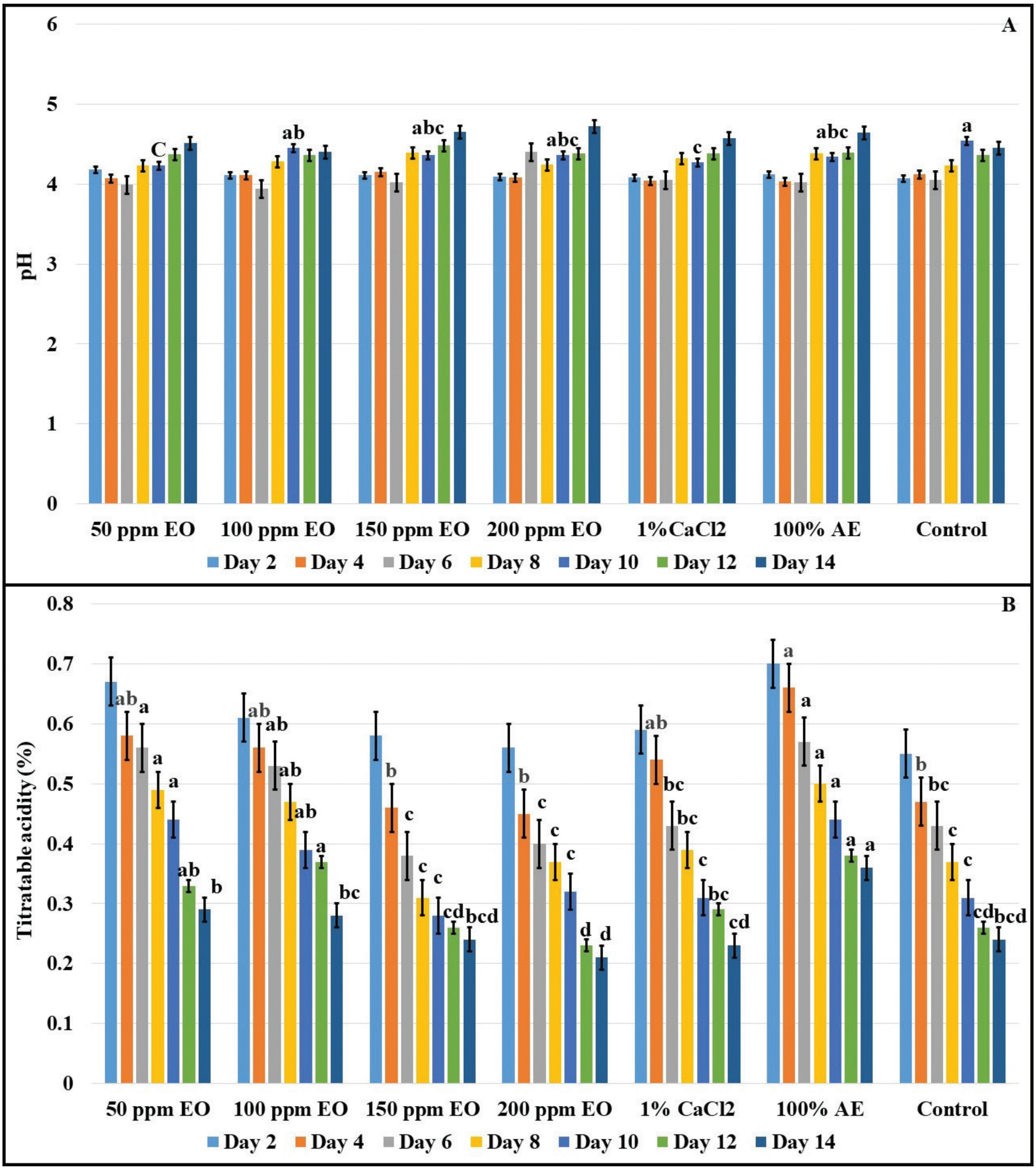

Figure 3. Effect of postharvest treatments on pH (**A**) and Tritatable acidity (**B**) during the lab experiment in 2021.

foods can delay spoilage for a few days, leading to an actual increase in vitamin levels due to ongoing natural metabolic processes (Sablani et al. 2006). The decline of Vitamin C with increasing storage time is primarily caused by the oxidation of ascorbic acid which could be due to the presence of catalyst and oxidizing enzymes (Žnidarčič et al. 2010).

TSS/TA ratio

Fruit palatability is frequently better correlated with the ratio of total soluble solids (TSS) to titratable acidity (TA) than with the amounts of sugar or acid alone. An increase in sugar content and a decrease in acidity are indicated by an increase in the TSS to TA ratio. There was a significant difference ($p < 0.05$) in the TSS/TA ratio among treatments during the experiment. Maximum ratio (21.08) was observed in 1% $CaCl_2$ treated tomatoes followed by 200 ppm essential oil treated tomatoes (17.12) whereas minimum ratio (9.92) was obtained in 100% Asuro Extract treated tomatoes followed by 50 ppm essential oil treated tomatoes (12.27) at 14 days after treatment as shown in Fig. 5. A higher ratio of TSS/TA is found to be superior because it contributes to superior flavor (Tietel et al. 2011).

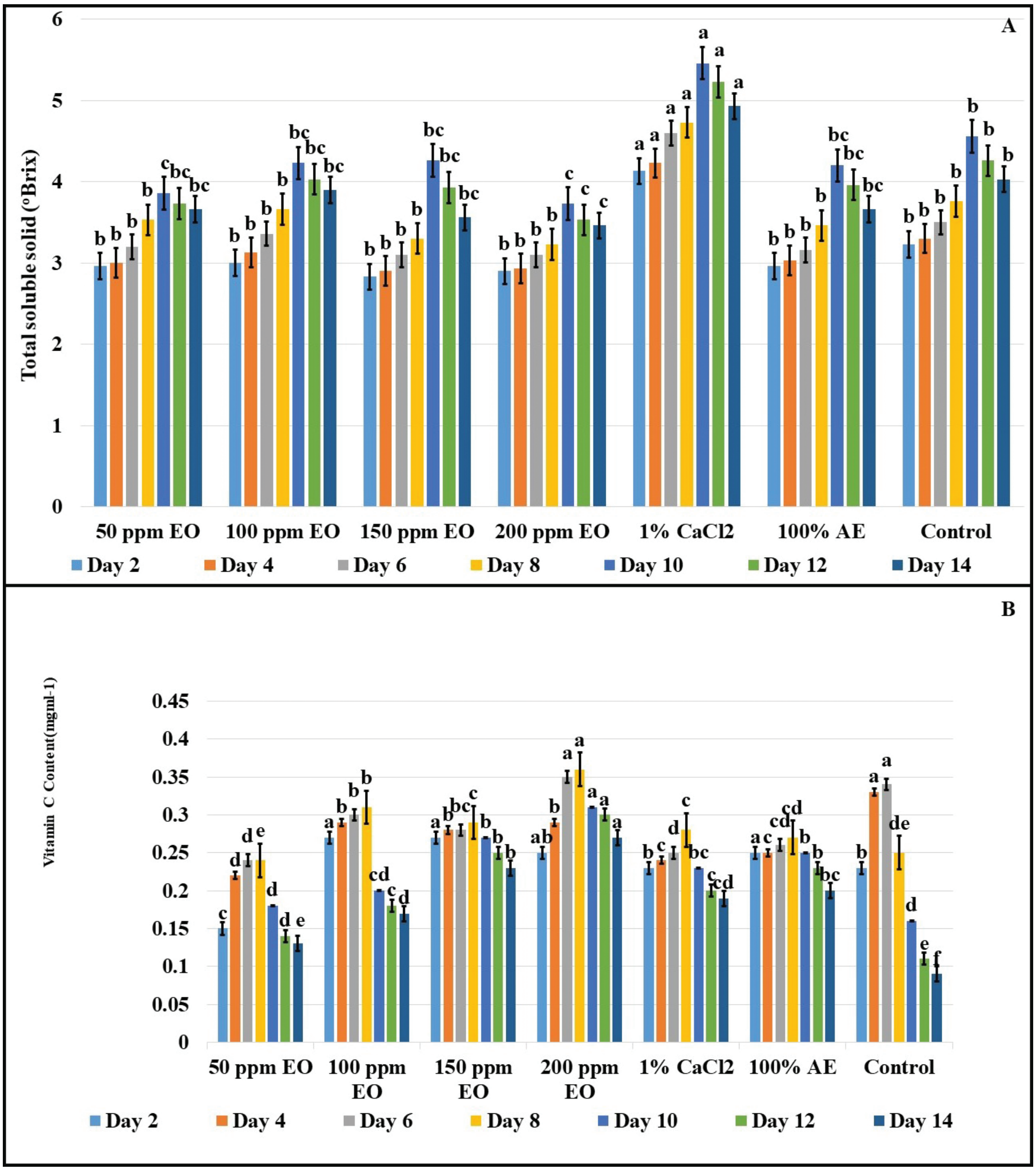

Figure 4. Effect of postharvest treatments on Total soluble solid (**A**) and Vitamin C (**B**) during the lab experiment in 2021.

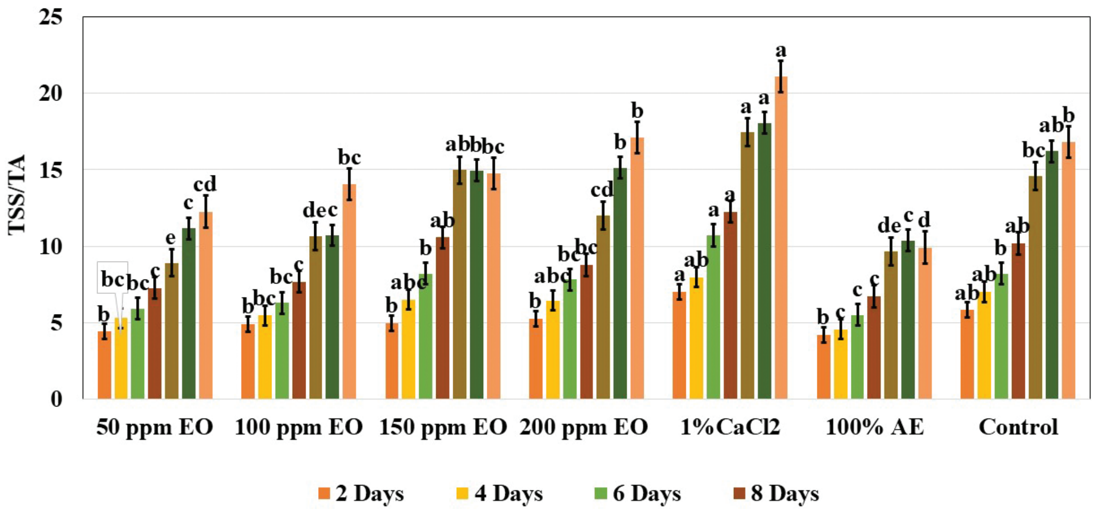

Figure 5. Effect of postharvest treatments on Total soluble solid (TSS)/Titratable acidity (TA) during the lab experiment in 2021.

Conclusion

Physicochemical parameters like TSS, TA, firmness, and Vitamin C showed significant differences among treatments whereas no significant difference in weight was observed. In conclusion, treatment at 200 ppm of EO was found to enhance overall physiochemical performance. Since the effect of EO on postharvest treatment of tomatoes was found to be effective at different concentrations, the use of chemicals can be replaced by non-hazardous essential oil. Among various concentrations of EO, 200 ppm was found to be the most effective and to confirm whether these findings are generalizable to other varieties. However, several long-term research and trials on a large scale along with different varieties of tomatoes are recommended for better confirmation. Also, the use of essential oils on a large scale might be challenging because of their higher price in comparison to chemicals. Researchers may use a mixture of essential oil and organic acids as solvents for new results.

Author contributions

Prachand Neupane: Conceptualization, Writing – original draft, Data curation, Formal analysis, Supervision; Balika Poudel: Writing – original draft, Writing – review and editing, Software, Validation; Binita Wosti: Conceptualization, Writing – original draft, Formal analysis, Methodology; Samikshya Pandey: Conceptualization, Writing – original draft, Formal analysis, Data curation; Mukesh Chaudhary: Conceptualization, Writing – original draft, Data curation, Investigation, Supervision; Ananda G.C.: Conceptualization, Writing – original draft, Software, Visualization; Ram Khanal: Conceptualization, Data curation, Formal analysis, Supervision; Jay Chaurasia: Writing – review and editing, Methodology, Supervision, Validation.

Conflict of interest

The authors hereby declare that they possess no conflict of interest in this paper.

Data availability statement

The data will be available on request to the corresponding author.

Ethics statement

The authors confirm that they have adhered to the ethical policy of the journal.

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Supplementary material

Supplementary material 1
Effect of postharvest treatment on weight loss (%) (docx)
Link: https://doi.org/10.3897/ia.2025.142908.suppl1