Original scientific paper
DOI: /10.5513/JCEA01/27.3.5051
Journal of Central European Agriculture, 2026, 27(3), p.736-747

Effects of postharvest treatments and storage temperatures on shelf-life extension of Keo Romeat mango (*Mangifera indica* L.)

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Received: October 10, 2025; accepted: December 8, 2025

ABSTRACT

The Keo Romeat mango (*Mangifera indica* L.) has a unique taste and is widely cultivated, especially in tropical regions. Mangoes deteriorate within a week during storage without preservation methods. $CaCl_2$ and $KMnO_4$ are known to be effective in preserving fruit quality. However, postharvest treatments alone are not the optimal method to preserve mango, while temperature is also one of the most effective factors for storage. This study aimed to assess the interaction and effect of postharvest treatments and temperature conditions. This study was conducted in a completely randomized design. The experiment included three treatments: no treatment (control), calcium chloride, and potassium permanganate, and each was stored under two temperature conditions, 10 ± 2 °C and 32 ± 2 °C. The results showed no significant interaction ($P > 0.05$) between postharvest treatments and storage temperature for weight loss, total soluble solids, and pH, except for acid concentration, which was significantly affected ($P < 0.05$). The efficacy of $CaCl_2$ and $KMnO_4$ did not differ significantly ($P > 0.05$), whereas 10 ± 2 °C and 32 ± 2 °C storage had significant differences ($P < 0.05$). $CaCl_2$ RF indicated the optimal weight loss (3.50 ± 0.63%), total soluble solids (8.10 ± 0.10%), pH (3.27 ± 0.10), and acid concentration (8.75 ± 0.81%). The combination of $CaCl_2$ treatment and storage at 10 ± 2 °C is recommended for maintaining the quality and extending the shelf life of mango.

Keywords: Keo Romeat mango, postharvest treatments, calcium chloride, refrigerated storage, shelf-life extension

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the economically important tropical fruits widely cultivated in tropical regions (Somaly et al., 2025). Particularly, the mango is rich in nutritional value and popular for its unique taste and high potential for export (Cook, 2024; Hin and Lim, 2024; Rajan, 2021). Growing mangoes is attracting more farmers to grow them due to their market price in local and international trade (Marcon et al., 2024). Recently, international trade has increased and comprises manufactured goods, which increased to 90.8% (Chan et al., 2025). Unfortunately, mango is a climacteric fruit that is perishable due to its high nutritional content after postharvest (Fatima et al., 2023). The physical and chemical qualities were changed as a result of respiration and enzyme activities, leading to rapid changes in colour, flavour, aroma, and texture (Nadeem et al., 2022; Rooban et al., 2016). These alterations cause the mango to deteriorate after harvest and storage within a week, resulting in huge quality loss (Ahmad et al., 2021; Lakshminarayana et al., 1970). In this case, calcium chloride ($CaCl_2$) is an important nutrient due to its role in cell wall structure. The components of the cellulose membrane can be bound

by the calcium ion (Ca^{2+}) to maintain the firmness of the cell (Gao et al., 2020). Based on earlier research, the application of $CaCl_2$ significantly lowered mango damage and extended the chemical quality (Zhang et al., 2019). Additionally, one of the popular and effective strategies for prolonging the shelf life of mangoes is potassium permanganate ($KMnO_4$) (Tran et al., 2024). Fruits naturally produce and release ethylene after harvest, which results in ripening. By binding to ethylene and oxidizing it to carbon dioxide and water, $KMnO_4$ lowers ethylene concentrations and delays the ripening process (Shaukat et al., 2023). Due to their efficient mechanism of inhibiting the deterioration process, including microorganisms, $CaCl_2$ and $KMnO_4$ are postharvest treatments that have been studied to extend shelf life and preserve the quality of fruits for long-term transportation (Abdelaleem et al., 2025; Sokra et al., 2024; Wu et al., 2025). $CaCl_2$ and $KMnO_4$ were proven to be safe at limited concentrations to treat fruit for storage and have become an essential focus of research in fruit preservation (Gao et al., 2019; Mishra et al., 2018). However, postharvest treatments alone are not an optimal method to prolong the shelf life of mangoes; particularly in temperature conditions, it is also a key factor influencing fruit deterioration (Ma et al., 2022). Ambient temperature is a risk condition that allows almost all enzymes and microorganisms to destroy fruit products (Sokra et al., 2025). To solve this, low temperatures were studied to determine how to enhance fruit quality (Hossain et al., 2014). Studies on temperature conditions showed that refrigerated temperature effectively reduced quality changes of fruits, such as 5 °C preservation of pomegranate fruits (Fawole and Opara, 2013), 4 °C preservation of blueberries (Wang et al., 2023), 4 °C preservation of pear fruit (Hong et al., 2024), and several conditions of mangoes were determined to be 20–23 °C (Gelaye, 2024) and 16 °C (Chaomuang et al., 2024). However, the combination of postharvest treatments and temperature lacked results of interaction and the effect of both factors.

This study aimed to assess the interaction and effect of postharvest treatments and temperatures, particularly which storage temperature is most effective for delaying quality deterioration in mangoes. This finding will determine the role of $CaCl_2$ and $KMnO_4$ inhibition under refrigeration and at room temperature in the mangoes during storage.

MATERIALS AND METHODS

Raw material

Three hundred sixty uniform, mature mangoes were purchased from a local farm in Kratie Province, Cambodia. Before the experiment, all mangoes were transported to the food science laboratory and washed with distilled water to remove any foreign matter. The excess water was then carefully removed, and the mangoes were gently blotted with tissue paper to avoid damage. The postharvest treatments ($CaCl_2$ and $KMnO_4$) were purchased from the Tianjin Dongda Chemical Group Co., Ltd., China and were utilized in the food science laboratory.

Experimental procedure plan

The experiment was conducted with a completely randomized design (CRD). The experiment involved two factors: the type of postharvest treatment ($CaCl_2$ and $KMnO_4$) and the storage temperature (10 ± 2 °C and 32 ± 2 °C). Measurements of all parameters were conducted at three-day intervals throughout the storage period. Each group consisted of thirty mangoes, with three replications, giving a total of 360 mangoes. The six experimental groups were established as follows:

- Control RF: without treatment and stored at 10 ± 2 °C
- Control RT: without treatment and stored at 32 ± 2 °C
- $CaCl_2$ RF: immersion in 2.5% $CaCl_2$ (w/v) solution for 15 min (Gao et al., 2020), stored at 10 ± 2 °C
- $CaCl_2$ RT: immersion in 2.5% $CaCl_2$ (w/v) solution for 15 min, stored at 32 ± 2 °C
- $KMnO_4$ RF: immersion in 0.5% $KMnO_4$ (w/v) solution for 15 min (Fatima et al., 2023), stored at 10 ± 2 °C
- $KMnO_4$ RT: immersion in 0.5% $KMnO_4$ (w/v) solution for 15 min, stored at 32 ± 2 °C.

Treatment process

For the control RF and control RT, the samples were dipped in distilled water for 15 minutes without any chemical treatment, then the excess water was removed. For the $CaCl_2$ and $KMnO_4$ treatments, mangoes were dipped in the respective solutions for 15 minutes. After the dipping step, all samples were rinsed with distilled water to remove residual chemicals and gently dried with soft tissue paper to avoid surface damage. Each treatment group was then stored at its designated temperature as described above (Figure 1).

Weight loss

To measure weight loss, five mangoes from each treatment were randomly selected every three days and weighed using a digital pocket electronic balance (model: SF-400C). Measurements were conducted for 18 days in the morning hours on days 0, 3, 6, 9, 12, 15, and 18. The percentage of weight loss at each time point was calculated following Lustriane et al. (2018) using the formula below:

$$\%\text{Weight loss} = \frac{W_0 - W_t}{W_0} \times 100$$

where:

W_0 = initial weight of the mango (g)

W_t = weight of the mango at time t (g).

Color (L, a*, b*)*

The flesh color of the mangoes was analyzed by capturing a photo using a high-resolution camera under standardized lighting conditions. The captured images were analyzed using ImageJ software (version 1.54p; National Institutes of Health, USA; https://imagej.org). The RGB values from selected regions of interest (ROIs) on the mango flesh surface were converted to the CIE Lab color space using the Color Transformer plugin or an equivalent built-in function in ImageJ. We represented lightness, redness, and yellowness, respectively, with the L*, a*, and b* values. The analysis was used to assess the surface color of mango flesh at the end of the experiment.

pH measurement

Fifty grams of mango juice were homogenized with 50 mL of distilled water and filtered through tissue paper. The pH of the filtrate was measured using a digital pH meter (827 pH Lab, Metrohm, Switzerland). Prior to measurement, the pH meter was calibrated using standard buffer solutions. The electrode was immersed in the mango juice sample, and the pH value was recorded after stabilization of the digital display, according to the procedure described by Somaly et al. (2025).

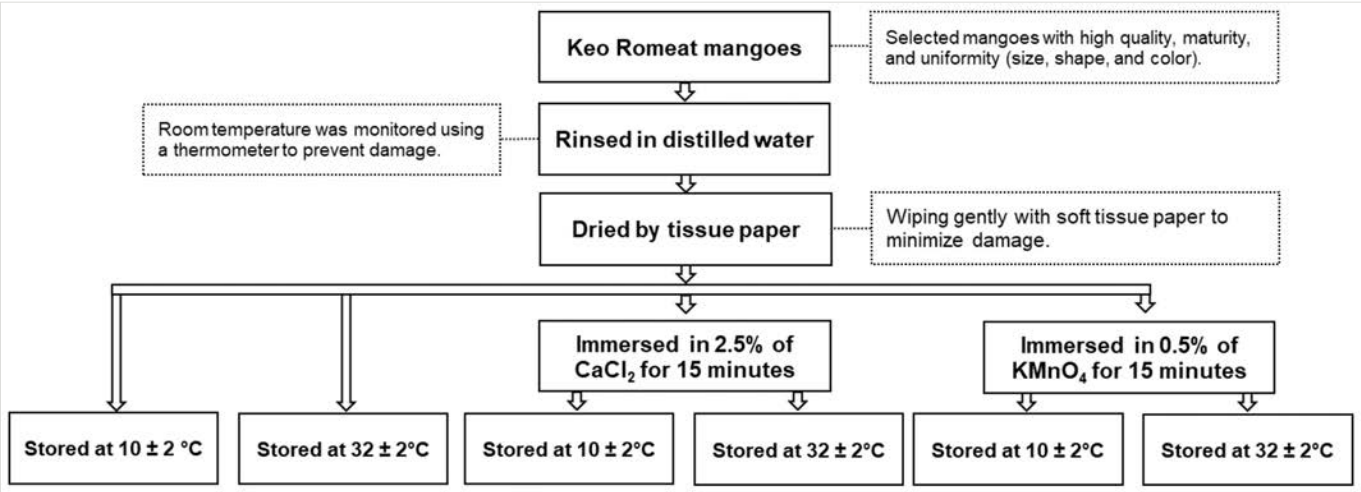


Figure 1. Diagram illustrating the postharvest treatments process for mangoes

Titratable acidity

To measure percentages of acid concentration, mangoes were measured according to AOAC International (2023). Mango fruit, weighing fifty grams, was homogenized with 50 mL of distilled water and filtered. A 10 mL mango juice filtrate was titrated with 0.1 N NaOH using phenolphthalein as an indicator until a light pink colour was observed. All recorded data were calculated and expressed as a percentage of citric acid.

$$\text{Titratable acidity (\% citric acid)} = \frac{V_{NaOH} \times N_{NaOH} \times 0.064 \times 100}{\text{Sample weight (g)}}$$

where:

V_{NaOH} = volume of NaOH used for titration (mL)

N_{NaOH} = normality of NaOH

0.064 = milliequivalent factor for citric acid

Soluble solid (°Brix)

Total soluble solids (TSS) were measured using a refractometer (model: PAL-1, China) after calibration with distilled water. Fifty grams of mango juice were homogenized with fifty millilitres of distilled water. Mango samples were filtered through tissue paper. Three drops of mango juice were placed on the screen of a refractometer, and data were recorded. The refractometer reports TSS in degrees Brix (°Brix), where 1 °Brix is equivalent to 1% (w/w) soluble solids. Therefore, all results were expressed in percentage (%) soluble solids (Sokra et al., 2024).

Statistical analysis

A CRD with three replications was conducted, using 105 mangoes per replicate and a total of 630 mangoes. Statistical analyses were performed using GraphPad Prism software (version 10.4.2, Windows, San Diego, California, USA; www.graphpad.com). Results were expressed as means ± standard deviations (SDs). Two-way ANOVA followed by Tukey's HSD multiple comparison test was applied, with significance set at $P < 0.05$.

RESULTS

Effect of color changes of mangoes during storage

Mangoes ripened rapidly within a week, including those treated with $CaCl_2$ and $KMnO_4$ when stored at room temperature. Likewise, the control mangoes, treated with $CaCl_2$ and $KMnO_4$, when stored at refrigerated temperature, were delayed until the end of the experiment (Figure 2).

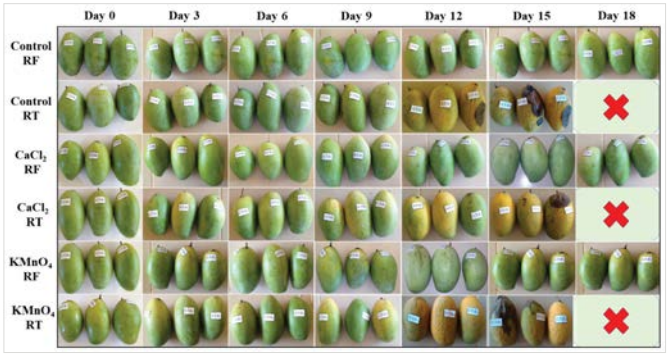


Figure 2. Effect of $CaCl_2$ and $KMnO_4$ treatments under different storage temperatures on sample quality (Control RF: samples without treatments, stored at 10 ± 2 °C; Control RT: samples without treatments, stored at 32 ± 2 °C; $CaCl_2$ RF: samples treated with $CaCl_2$ and stored at 10 ± 2 °C; $CaCl_2$ RT: samples treated with $CaCl_2$ and stored at 32 ± 2 °C; $KMnO_4$ RF: samples treated with $KMnO_4$ and stored at 10 ± 2 °C; $KMnO_4$ RT: samples treated with $KMnO_4$ and stored at 32 ± 2 °C)

$CaCl_2$ treatments showed the ability to delay the yellowing process of mango compared to the control and $KMnO_4$. However, all treatment groups that were stored at room temperature were completely ripened on day 12 and became spoiled by day 15. At the end of the experiment (day 18), the three remaining treatment groups that could be collected for the color analysis included control RF, $CaCl_2$ RF, and $KMnO_4$ RF when stored at refrigerated temperature (Figure 3).

The color parameters of the mangoes differed significantly ($P < 0.05$) across the treatments in terms of lightness (L*), redness-greenness (a*), and yellowness-blueness (b*). For lightness (L*), results showed that the mangoes treated with $KMnO_4$ obtained the highest values of 67.48 ± 1.20, demonstrating that treating mangoes with $KMnO_4$ and storing them at 10 ± 2 °C was the best choice to enhance the brightness.

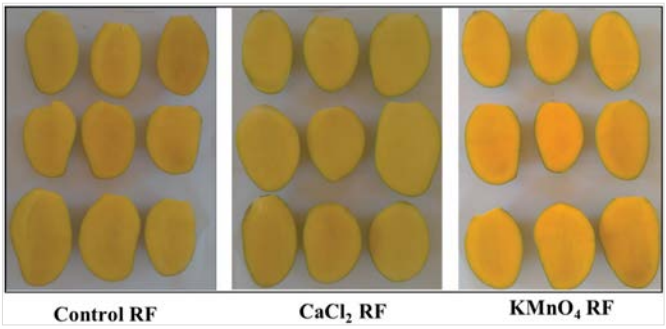


Figure 3. External color appearance of mangoes at the end of the experiment across three treatments groups (Control RF: samples without treatments, stored at 10 ± 2 °C; Control RT: samples without treatments, stored at 32 ± 2 °C; $CaCl_2$ RF: samples treated with $CaCl_2$ and stored at 10 ± 2 °C; $CaCl_2$ RT: samples treated with $CaCl_2$ and stored at 32 ± 2 °C; $KMnO_4$ RF: samples treated with $KMnO_4$ and stored at 10 ± 2 °C; $KMnO_4$ RT: samples treated with $KMnO_4$ and stored at 32 ± 2 °C)

This was followed by mangoes treated with $CaCl_2$ RF, which showed a high lightness value of 62.40 ± 8.38, indicating a strong effect, although still lower than that observed with $KMnO_4$ under refrigerated conditions. The control RF had the lowest lightness value of 54.75 ± 2.23, indicating a darker mango surface. For the red-green (a*) results, it was illustrated that $KMnO_4$ RF had a notably higher value of 21.74 ± 7.36, suggesting a stronger red colour, which may enhance ripening pigment development. The control RF and $CaCl_2$ RF groups did not differ significantly in reddish colour but were still high with values of 7.54 ± 1.65 and 3.16 ± 0.05, respectively. At 10 ± 2 °C, the control and $CaCl_2$ groups had lower values, showing a greener tone compared to $KMnO_4$. The yellow-blue (b*) result of mangoes showed that mangoes treated with $KMnO_4$ under refrigerated temperature obtained the highest value of 71.84 ± 1.93, indicating a stronger yellow colour.

This was followed by a control group value of 57.45 ± 0.64 and a $CaCl_2$ value of 53.14 ± 0.68 under refrigerated temperature, demonstrating that mango treated with $KMnO_4$ has the ability to enhance yellow coloration the most effectively.

At 10 ± 2 °C, $KMnO_4$ RF and $CaCl_2$ RF did not significantly affect the color of mango compared to the control RF. However, under refrigerated conditions, the $KMnO_4$-treated mangoes best preserved the characteristic color of the fruit, as indicated by the L*, a*, and b* values during storage.

Effect of all parameters of mangoes during storage under different temperature conditions

Figure 4 illustrates the effect of postharvest treatments and temperature conditions on the weight loss of mangoes. The two-way ANOVA illustrated no significant interaction between postharvest treatments and temperature conditions (Temp*Treat, $P > 0.05$), indicating the effect of postharvest treatments did not depend on the temperature conditions. The postharvest treatments showed no significant difference ($P > 0.05$), so $CaCl_2$ and $KMnO_4$ did not significantly affect the weight loss. The storage temperature had a significant effect ($P < 0.05$); post-hoc comparisons (Tukey's HSD) showed that refrigerated storage resulted in significantly lower weight loss than room temperature. Although mean values at individual treatment–temperature combinations differed numerically, these differences among treatments were not statistically significant. On day 12, the observed means (± SD, n = 5 per sampling) were: $CaCl_2$ RF 3.50 ± 0.63%, $KMnO_4$ RF 4.16 ± 0.81%, control RF 5.01 ± 2.87%,

Table 1. Color parameters (L*, a*, b*) of mangoes at the end of the experiment

Color	Control RF	Control RT	$CaCl_2$ RF	$CaCl_2$ RT	$KMnO_4$ RF	$KMnO_4$ RT
L*	54.75 ± 2.23^{b}	ND	62.40 ± 8.38^{ab}	ND	67.48 ± 1.20^{a}	ND
a*	7.54 ± 1.65^{b}	ND	3.16 ± 0.05^{b}	ND	21.74 ± 7.36^{a}	ND
b*	57.45 ± 0.64^{b}	ND	53.14 ± 0.68^{c}	ND	71.84 ± 1.93^{a}	ND

RF: refrigerator temperature; RT: Room temperature; ND: Not determined; L*: Lightness; a*: Redness; b*: Yellowness; a-c: Values within a column followed by different letters differ significantly ($P < 0.05$)

$KMnO_4$ RT 13.58 ± 0.36%, $CaCl_2$ RT 14.64 ± 0.92%, and control RT 14.65 ± 1.37%. These values show that refrigerated samples lost less weight than room temperature samples, consistent with the significant main effect of temperature.

The result of sugar content is shown in Figure 4b. The two-way ANOVA revealed no significant interaction between postharvest treatments and temperature conditions ($P > 0.05$), indicating the effect of postharvest treatments does not depend on the temperature conditions. The postharvest treatments showed no significant difference ($P > 0.05$), demonstrating that $CaCl_2$ and $KMnO_4$ did not significantly affect the sugar content. The temperature conditions had a significant effect ($P < 0.05$), meaning that different types of temperature conditions influence the sugar content value. From day 0 to day 12, the °Brix levels of mangoes increased in all groups, with a faster increase observed at room temperature than under refrigerated conditions. Two-way ANOVA indicated no significant interaction between postharvest treatments and storage temperature (Temp*Treat, $P > 0.05$), and the main effect of treatment was not significant ($P > 0.05$), indicating that $CaCl_2$ and $KMnO_4$ treatments did not significantly alter °Brix compared with the control. In contrast, storage temperature had a significant main effect ($P < 0.05$), with room temperature promoting higher °Brix values than refrigerated storage. On day 12, the observed mean °Brix values (± SD, n = 5 per sampling) were: $CaCl_2$ RF 6.5 ± 0.55, control RF 6.8 ± 0.27, $KMnO_4$ RF 7.1 ± 0.10, control RT 9.4 ± 0.46, $KMnO_4$ RT 9.6 ± 0.31, and $CaCl_2$ RT 11.3 ± 1.92. These values indicate that mangoes stored at 10 ± 2 °C accumulated sugar more slowly than those stored at 32 ± 2 °C, consistent with the significant effect of temperature.

The two-way ANOVA analysis of pH revealed a non-significant interaction between postharvest treatments and temperature conditions ($P > 0.05$), indicating that the effect of postharvest on pH does not depend on the temperature conditions. The postharvest treatments showed no significant difference ($P > 0.05$), demonstrating that $CaCl_2$ and $KMnO_4$ did not alter the pH levels. Conversely, temperature conditions had a significant effect ($P < 0.05$), meaning that different storage temperatures influenced pH value. From day 0 to day 12, the pH of mangoes increased in all groups, and the rate of increase was greater at 32 ± 2 °C than at 10 ± 2 °C. Mangoes stored at 32 ± 2 °C completely deteriorated after day 12. Two-way ANOVA showed no significant interaction between postharvest treatment and temperature (Temp * Treat, $P > 0.05$) and no significant main effect of treatment (Treat, $P > 0.05$), whereas temperature produced a significant main effect on pH (Temp, $P < 0.05$). These results indicated that $CaCl_2$ and $KMnO_4$ treatments did not significantly affect pH, but storage temperature influenced pH changes. In contrast, storage temperature had a significant main effect ($P < 0.05$), with refrigerated storage maintaining lower pH values than room temperature. On day 12, the observed mean pH values (± SD, n = 5 per sampling) were: $CaCl_2$ RF 3.31 ± 0.06, $KMnO_4$ RF 3.34 ± 0.06, control RF 3.42 ± 0.04, control RT 5.25 ± 0.09, $CaCl_2$ RT 5.25 ± 0.09, and $KMnO_4$ RT 5.31 ± 0.28. These results indicate that refrigerated mangoes maintained a more stable pH compared with those stored at room temperature, consistent with the significant effect of temperature.

Conversely, the two-way ANOVA of acid concentration reported a significant interaction between postharvest treatments and temperature conditions ($P < 0.05$). The highest acid concentration was observed in the $CaCl_2$ treatment at 10 ± 2 °C on day 12, reaching 8.31 ± 0.02%. At 32 ± 2 °C, all treatments showed a rapid decline in acid concentration, and the fruits totally deteriorated after day 12. In contrast, storage at 10 ± 2 °C slowed the decline and allowed clear differences among treatments to emerge, with $CaCl_2$ performing best, followed by $KMnO_4$ (8.13 ± 0.23%) and the control (7.25 ± 0.18%)

A key finding of this result suggests that within the first 12 days of storage, mangoes treated with $CaCl_2$ and $KMnO_4$ at 10 ± 2 °C showed the best preservation of chemical quality among the treatments.

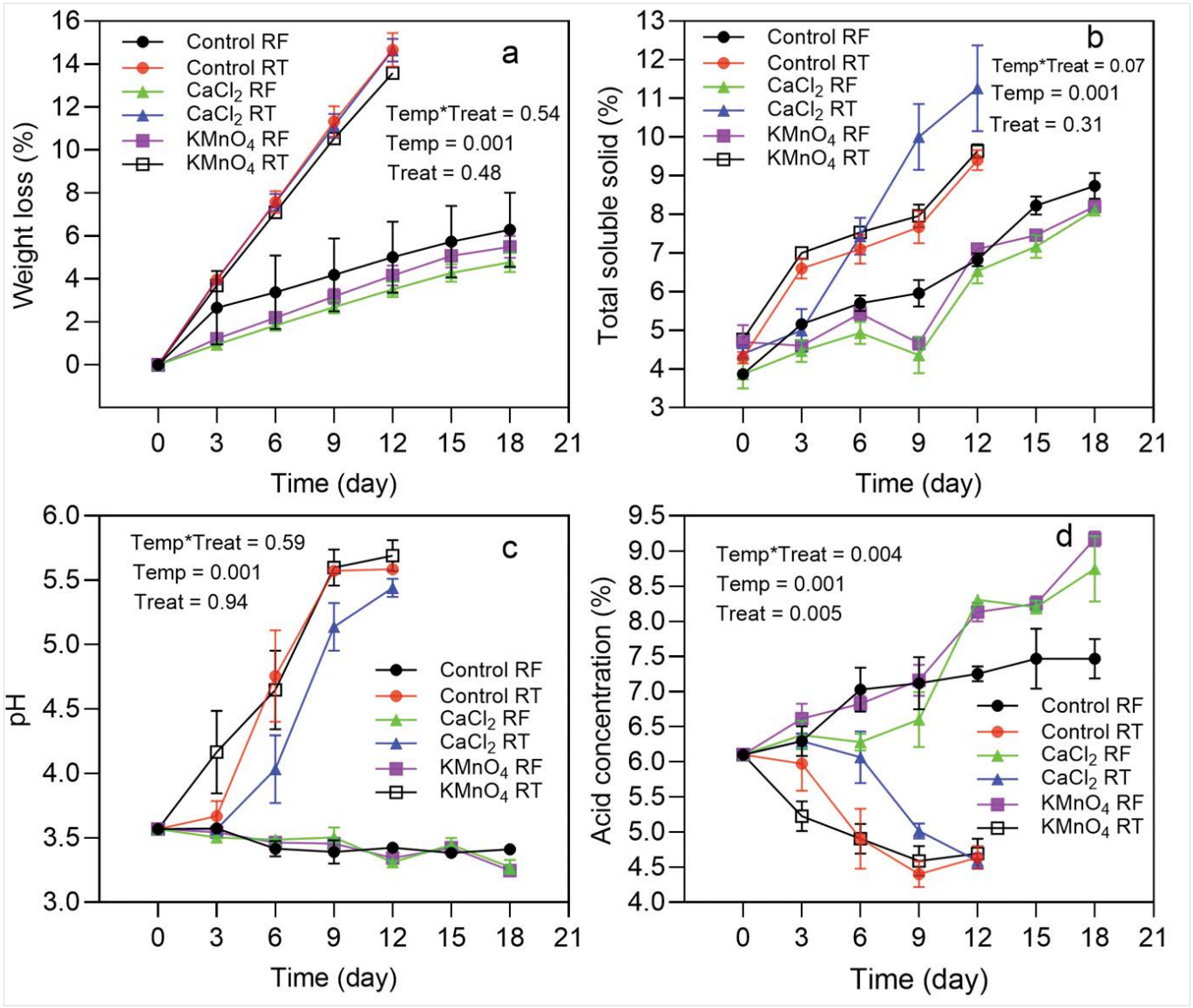


Figure 4. Interaction between storage temperature and postharvest treatments on selected quality parameters of the samples: (a) weight loss, (b) total soluble solids, (c) pH, and (d) acid concentration (Temp*Treat indicated the interaction between storage temperature and treatments; Temp referred to the main effect of temperature; Treat referred to the main effect of treatments. Values represented the results of two-way ANOVA ($P < 0.05$). RF: refrigerated temperature, RT: room temperature)

Effect of $CaCl_2$ and $KMnO_4$ on mango quality at 10 ± 2 °C

Because the mangoes stored at 32 ± 2 °C deteriorated by day 12, only samples kept at 10 ± 2 °C were measured until day 18. At 10 ± 2 °C, one-way ANOVA at each sampling day revealed no significant differences in weight loss among treatments ($P > 0.05$). Ithough $CaCl_2$ RF exhibited the lowest weight loss of 4.77 ± 0.79%, followed by $KMnO_4$ of 5.48 ± 0.89%, and the control RF of 6.28 ± 3%. Total soluble solids differed only on day 9 ($P < 0.05$), with no significant effects at other time points; at day 18, $CaCl_2$ RF showed the lowest value of 8.1 ± 0.10%, compared with $KMnO_4$ of 8.2 ± 0.10%, and the control RF of 8.8 ± 0.60%, respectively. For pH, all daily comparisons were non-significant ($P > 0.05$), yet $KMnO_4$ RF had the lowest pH at day 18 of 3.25 ± 0.03, followed by $CaCl_2$ of 3.27 ± 0.10 and the control RF of 3.41 ± 0.05. Acid concentration showed no differences at days 3, 6, and 9 ($P > 0.05$), but significant effects emerged at days 12, 15, and 18 ($P < 0.05$); at day 18, $KMnO_4$ RF recorded the highest concentration of 9.17 ± 0.18%, followed by $CaCl_2$ of 8.75 ± 0.81% and the control RF of 7.47 ± 0.49%.

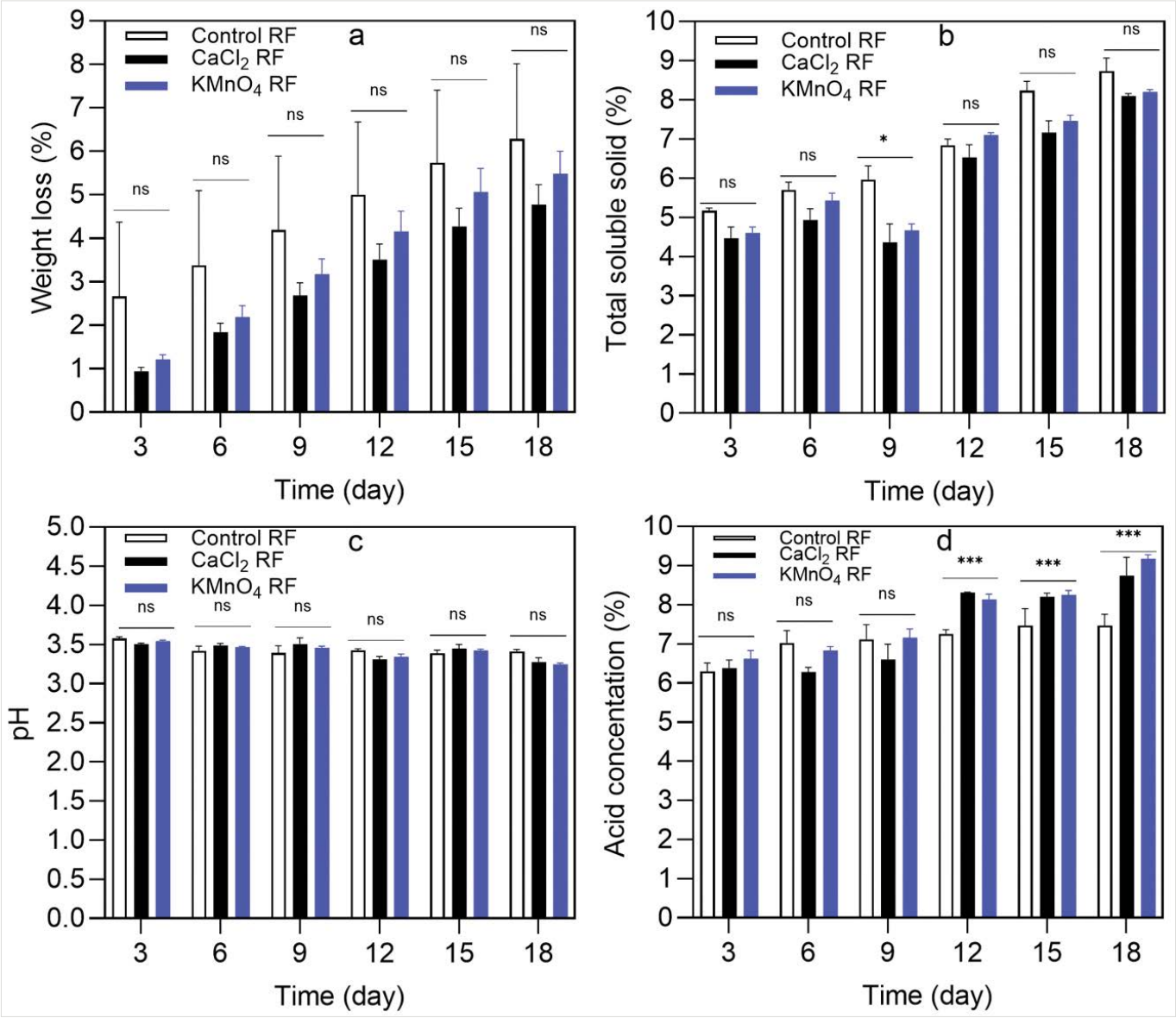


Figure 5. Effect of $CaCl_2$ and $KMnO_4$ treatments on mangoes stored at refrigerated temperature throughout the experiment (parameters include: (a) weight loss, (b) total soluble solids, (c) pH, and (d) acid concentration. ns indicates no significant difference; * indicates significant difference ($P < 0.05$). RF: refrigerated temperature, RT: room temperature)

Overall, $CaCl_2$ RF was the most effective treatment for maintaining the chemical quality of mangoes up to 18 days, while both $CaCl_2$ and $KMnO_4$ contributed to slower ripening and better preservation of organic acids than the control RF.

DISCUSSION

In fruits, calcium ions serve as essential multifunctional signaling ions that facilitate the formation of cell walls, membrane regulation, and the activation of various pathways of cell signaling (Gao et al., 2020; Jaime-Guerrero et al., 2024; Larocca et al., 2025). By reducing ethylene gas, a naturally occurring plant hormone that triggers ripening and senescence, $KMnO_4$ may have been shown to be useful in extending the post-harvest maturity of fruit (Álvarez-Hernández et al., 2019; Fatima

et al., 2023). Temperature is one of the most important factors affecting fruit ripening, as it slows the biochemical processes responsible for senescence and spoilage (Badia-Melis et al., 2016; Honorato, 2020; Vicente et al., 2002). Both postharvest treatments and temperature conditions were extensively observed for their roles in extending fruit shelf life. However, the combined effects of these treatments are still lacking in research.

The experiment observed the effect of postharvest treatments and temperature conditions on the shelf life of mangoes. The six treatment combinations were studied, consisting of three levels of postharvest treatments (control, $CaCl_2$, and $KMnO_4$) and two levels of storage conditions (room and refrigerated storage). The results on color changes showed no significant interaction between postharvest and temperature conditions. $CaCl_2$ and $KMnO_4$ did not have a significant effect compared to the control group. However, refrigerated temperature showed a significant effect on mango storage during 18 days. The group treated with $CaCl_2$ under refrigerated temperature is the most effective in preserving the color change of mangoes. $CaCl_2$ is an organic substance that inhibits the synthesis of pigments and the breakdown of chlorophyll (Bitange et al., 2021). $CaCl_2$ application to the mango under refrigeration was the most effective at preserving color, most likely due to the reduced enzymes that break down cell walls, such as cellulase, β-galactosidase, polygalacturonase, and pectin methyl esterase (Abdelaleem et al., 2025; Wu et al., 2025). $KMnO_4$ also affects fruit color during storage by reducing postharvest enzyme activity, which is aligned with Belwal et al. (2023). Tran et al. (2024) revealed that $KMnO_4$ delayed the release of ethylene, which in turn slowed the color change of the mango. However, mangoes treated with $CaCl_2$ and $KMnO_4$ and stored at room temperature did not significantly alter the color change; rather, as the storage temperature increased, noticeable color changes were observed (Deng et al., 2022). Fruit stored at room temperature exhibited a quick color change within a week due to enzyme activity, specifically the rate of ethylene, which turned the peel yellow (Ahmad et al., 2021). Overall, the best way to maintain the color of mangoes was to apply $CaCl_2$ treatments in cold weather. This supports the results of Baltazari et al. (2019), who found that preserving fruit color and extending shelf life can be achieved by combining optimal postharvest treatments with the right temperature.

The measurement of parameters—including weight loss, sugar content, and pH levels (excluding citric acid)—showed no significant interaction between chemicals and temperature conditions during the first 12 days of the storage experiment. Postharvest treatments ($CaCl_2$ and $KMnO_4$) did not significantly affect the chemical quality of mangoes, whereas temperature conditions had a significant effect on quality changes throughout the storage period. By day 18, the treatment group that treated mangoes with postharvest and stored them under refrigerated conditions retained optimal quality, while those stored at room temperature had entirely deteriorated. Among the treatments, $CaCl_2$ was the most effective in preserving chemical parameters under refrigerated temperature. This result is aligned with the findings of Somaly et al. (2025), who revealed that mangoes stored at room temperature rapidly deteriorated within a week. Currently, the mango is a widely grown Cambodian variety that typically begins to ripen within a few days after harvest under ambient temperature conditions (Hin and Lim, 2024; Kuldeep et al., 2025; Liu et al., 2023). Mango is a climacteric fruit, which makes it easy to increase the ethylene levels and respiration rate, leading to rapid, accelerated ripening. This study is consistent with Nadeem et al. (2022), who indicated that mangoes stored at ambient temperature often deteriorate after a few days due to their high respiration rate and enzyme activities. Treating fruits with a suitable concentration of $CaCl_2$ significantly inhibits metabolic activity in mango tissues, protecting against weight loss, avoiding deterioration, and preserving chemical quality (Gao et al., 2020). $CaCl_2$ plays an essential role in maintaining the structure of plant tissues by stabilizing both cell membranes and cell walls. It does this largely through interactions with pectins in the middle lamella, resulting in cross-linking that slows fruit softening and limits cellular damage (Bitange et al., 2021). This method of preservation is especially

relevant for mangoes, which tend to undergo rapid physiological transformations as they ripen (Somaly et al., 2025). At room temperature—particularly around 30 °C - there is a high increase in the activity of enzymes such as polygalacturonase, pectin methyl esterase, and cellulase. These enzymes directly function in the destruction of fruit softening, cell membranes, and subsequent changes in both texture and sugar content.

The ripening enzyme activity of mangoes was slowed, and changes in chemical quality were delayed when the fruit was stored under refrigeration (Hossain et al., 2014). Similar observations were made by Ma et al. (2022), who reported that postharvest treatment combined with cold storage resulted in minimal weight loss, restricted sugar accumulation, reduced respiration rate, and lower enzyme activity. Moreover, combining the application of $CaCl_2$ and refrigeration improves the ability to preserve the chemical integrity of the fruit and may provide advantages for commercial postharvest management. Delaying postharvest losses is a key concern in tropical and subtropical fruit production, particularly in Cambodia where cold chain infrastructure is still developing. By applying $CaCl_2$—a low-cost and accessible treatment—together with refrigeration storage, producers can extend the overall shelf life and maintain the chemical quality of mangoes, ensuring greater economic returns and reducing food waste. Based on this study, the combination of $CaCl_2$ and refrigerated storage conditions proves to be an effective method for preserving the color and chemical quality of mangoes.

CONCLUSION

This study proved that $CaCl_2$ and refrigerated storage (10 ± 2 °C) provided notable benefits for mango preservation. The combination treatment ($CaCl_2$ RF) of this study effectively prolonged the shelf life while maintaining quality parameters (color retention, weight stability, and chemical composition). These results demonstrate successful storage for up to 18 days without significant quality deterioration. These findings have important practical implications for the mango supply chain, offering farmers and vendors an accessible method to reduce postharvest losses. The prolonged storage period facilitates safer transportation and expands opportunities in the market for this important fruit variety. This effective preservation method could substantially benefit local agricultural economies while improving fruit availability for consumers.

ACKNOWLEDGEMENT

The authors sincerely thank the University of Kratie for supporting this study and for allowing the use of laboratory equipment.

REFERENCES

Abdelaleem, H. M., El-Dkeshy, M. H. Z., Abdalla, R. M. (2025) Preharvest spraying of calcium chloride, chitosan, and their combination effects on tomato growth, yield, fruit characteristics, and quality. Assiut Journal of Agricultural Sciences, 56 (1), 296–313. DOI: https://doi.org/10.21608/ajas.2025.330403.1417

Ahmad, F., Zaidi, S., Arshad, M. (2021) Postharvest quality assessment of apple during storage at ambient temperature. Heliyon, 7 (8), e07714. DOI: https://doi.org/10.1016/j.heliyon.2021.e07714

Álvarez-Hernández, M. H., Martínez-Hernández, G. B., Avalos-Belmontes, F., Castillo-Campohermoso, M. A., Contreras-Esquivel, J. C., Artés-Hernández, F. (2019) Potassium permanganate-based ethylene scavengers for fresh horticultural produce as an active packaging. Food Engineering Reviews, 11 (3), 159–183. DOI: https://doi.org/10.1007/s12393-019-09193-0

AOAC International. (2023) Official methods of analysis of AOAC International. Oxford University Press. DOI: https://doi.org/10.1093/9780197610145.001.0001

Badia-Melis, R., McCarthy, U., Uysal, I. (2016) Data estimation methods for predicting temperatures of fruit in refrigerated containers. Biosystems Engineering, 151, 261–272. DOI: https://doi.org/10.1016/j.biosystemseng.2016.09.009

Baltazari, A., Mtui, H. D., Mwatawala, M. W., Chove, L. M., Msogoya, T., Samwel, J., Subramanian, J. (2019) Effect of storage conditions, storage duration and post-harvest treatments on nutritional and sensory quality of orange (*Citrus sinensis* (L.) Osbeck) fruits. International Journal of Fruit Science, 20 (4), 737–749. DOI: https://doi.org/10.1080/15538362.2019.1673278

Belwal, P., Singh, A. K., Pal, A. K., Sharma, S., Barman, K. (2023) Effect of potassium permanganate on postharvest quality attributes of bitter gourd fruit. Vegetable Science, 50 (1), 39–45. DOI: https://doi.org/10.61180/vegsci.2023.v50.i1.05

Bitange, N. M., Chemining'wa, G. N., Ambuko, J. L., Owino, W. O. (2021) Effect of mode and timing of calcium chloride application in tissue calcium concentration and acceptability of mango fruits. African Journal of Food, Agriculture, Nutrition and Development, 21 (103), 18552–18573. DOI: https://doi.org/10.18697/ajfand.103.20350

Chan, J. M. L., Irlacher, M., Koch, M. (2025) Multiproduct Firms, Horizontal Mergers, and International Trade. The Review of Economics and Statistics, 1–45. DOI: https://doi.org/10.1162/rest.a.255

Chaomuang, N., Laguerre, O., Denis, A., Paviet-Salomon, Y., Mawilai, P., Srisawat, K., Derens-Bertheau, E., Ndoye, F. T., Pongsuttiyakorn, T., Rakmae, S., Pun, U. K., Sirisomboon, P., Pornchaloempong, P., Duret, S. (2024) Experimental study of air cargo temperature variations and its impact on mango quality. International Journal of Refrigeration, 160, 129–140. DOI: https://doi.org/10.1016/j.ijrefrig.2024.02.009

Cook, B. (2024) Uptake of agricultural technologies and best practices amongst farmers in Battambang and Pailin provinces, Cambodia. Australian Centre for International Agricultural Research (ACIAR).

Deng, L. Z., Xiong, C. H., Pei, Y. P., Zhu, Z. Q., Zheng, X., Zhang, Y., Yang, X. H., Liu, Z. L., Xiao, H. W. (2022) Effects of various storage conditions on total phenolic, carotenoids, antioxidant capacity, and color of dried apricots. Food Control, 136, 108846. DOI: https://doi.org/10.1016/j.foodcont.2022.108846

Fatima, F., Basit, A., Younas, M., Shah, S. T., Sajid, M., Aziz, I., Mohamed, H. I. (2023) Trends in potassium permanganate (ethylene absorbent) management strategies: Towards mitigating postharvest losses and quality of mango (*Mangifera indica* L.) fruit. Food and Bioprocess Technology, 16(10), 2172–2183. DOI: https://doi.org/10.1007/s11947-023-03047-8

Fawole, O. A., Opara, U. L. (2013) Effects of storage temperature and duration on physiological responses of pomegranate fruit. Industrial Crops and Products, 47, 300–309. DOI: https://doi.org/10.1016/j.indcrop.2013.03.028

Gao, Q., Tan, Q., Song, Z., Chen, W., Li, X., Zhu, X. (2020) Calcium chloride postharvest treatment delays the ripening and softening of papaya fruit. Journal of Food Processing and Preservation, 44 (8), e14604. DOI: https://doi.org/10.1111/jfpp.14604

Gao, Q., Xiong, T., Li, X., Chen, W., Zhu, X. (2019) Calcium and calcium sensors in fruit development and ripening. Scientia Horticulturae, 253, 412–421. DOI: https://doi.org/10.1016/j.scienta.2019.04.069

Gelaye, Y. (2024) A review of storage temperature and relative humidity effects on shelf life and quality of mango (*Mangifera indica* L.) fruit and implications for nutrition insecurity in Ethiopia. Open Agriculture, 9 (1), 1–9. DOI: https://doi.org/10.1515/opag-2022-0296

Hin, K., Lim, S. (2024). An assessment of the supply chain management for agricultural product in Cambodia. Edelweiss Applied Science Technology, 8 (6), 6757–6770. DOI: https://doi.org/10.55214/25768484.v8i6.3456

Hong, P., Zhang, J., Shi, D., Yang, C., Zeng, M., Li, X., Zhou, K., Xi, W. (2024) Postharvest application of methyl jasmonate alleviates lignin accumulation in stone cells of pear fruit during low-temperature storage. Postharvest Biology and Technology, 209, 112692. DOI: https://doi.org/10.1016/j.postharvbio.2023.112692

Honorato, C. P. (2020) Temperature simulation and control in refrigerated storage chambers for fruit. Procedia Manufacturing, 42, 35–40. DOI: https://doi.org/10.1016/j.promfg.2020.02.021

Hossain, M. A., Rana, M. M., Kimura, Y., Roslan, H. A. (2014) Changes in biochemical characteristics and activities of ripening-associated enzymes in mango fruit during the storage at different temperatures. BioMed Research International, 2014, 1–11. DOI: https://doi.org/10.1155/2014/232969

Jaime-Guerrero, M., Álvarez-Herrera, J. G., Fischer, G. (2024) Effect of calcium on fruit quality: A review. Agronomía Colombiana, 42 (1), e112026. DOI: https://doi.org/10.15446/agron.colomb.v42n1.112026

Kuldeep, A. K. S., Rawat, M., Shivam, G. M., Gautam, R., Raj, R., Shah, I., Pandey, A. K., Maurya, D., Singh, S. N., Kumar, V. (2025) Postharvest physiology of mango crops: Understanding ripening, quality, and storage strategies. Applied Fruit Science, 67 (2), 60. DOI: https://doi.org/10.1007/s10341-025-01273-2

Lakshminarayana, S., Subhadra, N. V., Subramanyam, H. (1970) Some aspects of developmental physiology of the mango fruit. Journal of Horticultural Science, 45 (2), 133–142. DOI: https://doi.org/10.1080/00221589.1970.11514339

Larocca, G. N., Baldi, E., Toselli, M. (2025) Understanding the role of calcium in kiwifruit: Ion transport, signalling, and fruit quality. Horticulturae, 11 (3), 335. DOI: https://doi.org/10.3390/horticulturae11030335

Liu, B., Xin, Q., Zhang, M., Chen, J., Lu, Q., Zhou, X., Li, X., Zhang, W., Feng, W., Pei, H., Sun, J. (2023) Research progress on mango post-harvest ripening physiology and the regulatory technologies. Foods, 12 (1), 173. DOI: https://doi.org/10.3390/foods12010173

Lustriane, C., Dwivany, F. M., Suendo, V., Reza, M. (2018) Effect of chitosan and chitosan nanoparticles on postharvest quality of banana fruits. Journal of Plant Biotechnology, 45 (1), 36–44. DOI: https://doi.org/10.5010/JPB.2018.45.1.036

Ma, Y., Zhang, W., Cheng, S., Liu, Y., Yang, W., Wang, Y., Guo, M., Chen, G. (2022) Postharvest storage at near-freezing temperature maintained the quality and antioxidant properties of *Prunus domestica* L. cv. *Ximei* fruit. Scientia Horticulturae, 293, 110720. DOI: https://doi.org/10.1016/j.scienta.2021.110720

Marcon, S., Giuliani, A., Tivet, F., Rath, S., Roeun, R., Phoeng, P., Sar, V. (2024) Cover crops implementation in mango and longan orchards in Battambang province, Cambodia. Journal of Agricultural Science, 7 (2), 102–115. DOI: https://doi.org/10.31186/j.agritropica.7.2.102-115

Mishra, V., Abrol, G. S., Dubey, N. (2018) Sodium and calcium hypochlorite as postharvest disinfectants for fruits and vegetables. In: Siddiqui, M. W., ed. Postharvest disinfection of fruits and vegetables. Academic Press, pp. 253–272.

Nadeem, A., Ahmed, Z. F. R., Hussain, S. B., Omar, A. E. D. K., Amin, M., Javed, S., Ali, A., Ullah, S., Razzaq, K., Rajwana, I. A., Nayab, S., Ziogas, V., Alam-Eldein, S. M., Mira, A. M. (2022) On-tree fruit bagging and cold storage maintain the postharvest quality of mango fruit. Horticulturae, 8 (9), 81–94. DOI: https://doi.org/10.3390/horticulturae8090814

Rajan, S. (2021) Mango: The king of fruits. In C. Kole (Ed.), The mango genome (pp. 1–11). Springer International Publishing. DOI: https://doi.org/10.1007/978-3-030-47829-2_1

Rooban, R., Shanmugam, M., Venkatesan, T., Tamilmani, C. (2016) Physiochemical changes during different stages of fruit ripening of climacteric fruit of mango (*Mangifera indica* L.) and non-climacteric of fruit cashew apple (*Anacardium occidentale* L.). Journal of Applied and Advanced Research, 1 (2), 53–58. DOI: https://doi.org/10.21839/JAAR.2016.V1I2.27

Shaukat, M. F., Hussain, I., Mehmood, A., Naveed, K., Ayub, A., Ayub, Q., Ali, R. A., Malik, M. A. M., Ahmed, J., Ahmad, M. (2023) Improving storability and quality of peach fruit with post-harvest application of calcium and permanganate. Pure and Applied Biology, 12 (1), 414–423. DOI: https://doi.org/10.19045/bspab.2023.120044

Sokra, I., Lika, R., Meta, H., Chanra, R., Linan, H., Pang, T., Sarun, H. (2024) Extending shelf-life and preserving the quality of lady finger banana (Μυσα αχυμινατα) via various postharvest treatments. International Journal of Science and Research Archive, 12 (2), 2636–2645.

DOI: https://doi.org/10.30574/ijsra.2024.13.2.2460

Sokra, I., Meta, H., Chanra, R., Linan, H., Pang, T., Sarun, H. (2025) Different microorganisms used in fermentation for biofertilizer: A review. Journal of Agriculture and Technology, 1 (1), 41–65. DOI: https://doi.org/10.5281/zenodo.15655617

Somaly, S., Lika, R., Socheata, C., Sokra, I. (2025) Effect of blanching temperature and time on chemical properties of Keo Romeat mango (*Mangifera indica*) in Cambodia. Journal of Agriculture and Technology, 1 (2), 37–46. DOI: https://doi.org/10.5281/zenodo.15461055

Tran, T. T., Le, T. T. T., Nguyen, H. P. (2024) Effectiveness of $KMnO_4$ and activated carbon on the quality and storage properties of mango fruit. Advances in Horticultural Science, 38 (3), 233–238. DOI: https://doi.org/10.36253/ahsc-15769

Vicente, A. R., Martínez, G. A., Civello, P. M., Chaves, A. R. (2002) Quality of heat-treated strawberry fruit during refrigerated storage. Postharvest Biology and Technology, 25 (1), 59–71. DOI: https://doi.org/10.1016/S0925-5214(01)00142-9

Wang, J., Shi, C., Fang, D., Che, J., Wu, W., Lyu, L., Li, W. (2023) The impact of storage temperature on the development of microbial communities on the surface of blueberry fruit. Foods, 12 (8), 1611. DOI: https://doi.org/10.3390/foods12081611

Wu, Y., Dong, X., Zhu, Y., Chen, H. (2025) Influence of pre-harvest sprays of calcium chloride on fruit storage quality and softening of 'Fengtangli' (*Prunus salicina* L.) plum. CyTA – Journal of Food, 23 (1), 2446834. DOI: https://doi.org/10.1080/19476337.2024.2446834

Zhang, L., Wang, J., Chen, J., Song, T., Jiang, Y., Zhang, Y., Li, W., Li, F. (2019) Preharvest spraying calcium ameliorated aroma weakening and kept higher aroma-related gene expression level in postharvest 'Nanguo' pears after long-term refrigerated storage. Scientia Horticulturae, 247, 287–295. DOI: https://doi.org/10.1016/j.scienta.2018.12.038